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Volume LXXXIII

BOTANY

Number 1

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MARCH 1927

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Volume LXXXIII Number 1

THE BOTANICAL GAZETTE

A JOURNAL EMBRACING ALL DEPARTMENTS OF BOTANICAL SCIENCE

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For March 1927 and April 1927

The World and Man

The advance of modern science has revealed a vast store of fascinating facts about the universe in which we live. More discoveries have been made in nearly every branch of science in the past two or three decades than in all the previous history of mankind. Scientists have disclosed a world of the infinitely small in electrons, atoms, and molecules; and of the enormously large in giant suns and galaxies of stars, billions of miles distant. They have looked back millions of years to the origins of worlds, and have traced their history through the geological ages to the present. Myriads of plants and animals have been studied, from the lowliest bacteria and protozoa up to man. Minute investigation of man himself—his origin, the wonders of his body, the development of his intelligence—has yielded astonishing facts. Inanimate matter has revealed marvelous secrets to the modern chemist. The physicist has explained the forces we see about us every day, and the biologist is seeking to explain the very secret of life itself.

To help the inquiring reader in his efforts to keep up with the procession of modern science, sixteen members of the Faculty of the University of Chicago have written *The Nature of the World and of Man*, which E. E. Slosson describes as a book for "those who have not been to college and those who have."

These men, specialists in their fields, are the authors: Forest Ray Moulton, Rollin T. Chamberlin, J Harlen Bretz, Harvey B. Lemon, Julius Stieglitz, Horatio Hackett Newman (the editor), Edwin Oakes Jordan, Merle C. Coulter, Henry Chandler Cowles, Warder C. Allee, Alfred S. Romer, Fay-Cooper Cole, Elliot R. Downing, George W. Bartelmez, Anton J. Carlson, and Charles Hubbard Judd.

Beginning with the outstanding facts about the solar system, each of the sixteen authors has described that phase of development with which he is most familiar: the origin and early stages of the earth; geological processes and the earth's history; the nature of energy and matter; bacteria and their origin; evolution of the plant kingdom, the vertebrates, and the invertebrates; interactions between plants and their environment; the coming of man; organic evolution and the origin of life; human inheritance; structure of man; the living process; and mind in evolution.

Throughout, the authors have emphasized the conception of science as a glowing, living thing inextricably bound up with every human life. With all its multiplicity of authorship, the book has (in the words of the *Chicago Tribune*) "taken on the unity, the coherence, the march of one great epic poem."

Stuart Pratt Sherman said not long ago: "I have a strong impression that our 'average' American is waking up, responding to the new emphasis on 'adult education,' becoming infatuated with the idea of having his education go on as long as he does. He has got wind of the secret that in all the fields of knowledge enormous changes and advances have been made in the last twenty-five years and are still being made at this present hour. His sporting desire to keep up with his times grows keener and the range of his curiosity will soon be encyclopedic."

The popularity of *The Nature of the World and of Man* is evidence of the awakening of the adult public to the possibilities of

further education. For the reader outside the universities the book is a guide to the world of contemporary science; it enables him to form a conception of how the earth came to be, what its place is in the vast physical universe, how life originated; it gives him glimpses of the monsters of early ages; shows him how Cro-Magnon man lived, how atoms are held together in a molecule, how invisible throngs of bacteria surround us, how life came from the sea to the land, why insanity is increasing, how speech developed, how hormones regulate bodily processes. . . . .

The Nature of the World and of Man contains the subject matter of a "survey course" given each year by its authors to a selected group of beginning students at the University of Chicago. The success of the experiment upon which it is based suggests a wide use of this text in similar courses in other institutions to give the beginner a preliminary view of the surrounding world and of his possible function in it.

In this day of increasing specialization and a confusingly large body of human knowledge, orientation toward the more general aspects of the world and of man is a necessity. In the belief of the authors of this text, orientation may best begin with a presentation of what modern science holds as truth. They have therefore attempted to give the student that acquaintance with the general outlines of scientific thought which is the ideal point of departure for his entire intellectual development, and which alone affords him the proper perspective on the world of modern thought. More specialized courses in thinking, man in society, or the arts, may well follow, but this course, being more informational, more inclusive, and easier for the beginner should be the point of departure. *THE NATURE OF THE WORLD AND OF MAN.* By SIXTEEN MEMBERS OF THE FACULTY OF THE UNIVERSITY OF CHICAGO. *$4.00, postpaid $4.15.*

* * *

Current American Prose

In a volume of provocative essays, *The Outlook for American Prose*, Joseph Warren Beach searches the current prose of reflection, reminiscence, criticism, and social commentary for auguries of a first-rate style. He judges as stylists the American prose artists who are now in the public eye. Timely and incisive comment from this candid and erudite observer will be not unwelcome to readers who have become aware of the development of American prose style in such books as *Troubadour, Straws and Prayer-Books*, and *A Story-Teller's Story*.

A professed eclectic, and adherent of no particular school or tendency, Mr. Beach seeks the perfect style wherever it may be found. Looking about for American writers of cultivated philosophical prose to compare with Bertrand Russell and Havelock Ellis; biographers to rank with Lytton Strachey; newspaper essayists to place beside Chesterton; and critics as stimulating as Shaw, he advances a gratifying number of claimants to distinction. In Sherwood Anderson, James Branch Cabell, H. L. Mencken, Stuart Pratt Sherman, Paul Rosenfeld, Simeon Strunsky, and Alfred Kreymborg, Mr. Beach finds the most hopeful signs of a distinguished prose art in America, and whether or not you agree with him, you will have to reckon with his arresting dicta on the luminaries of the day.

"Old fashioned or new fashioned, what we want is something first rate," says Mr. Beach. His regard for stylistic perfection leads him to protest against the incoherence of Hergesheimer; the lack of precision in John Dewey; the naïveté of Dreiser; the scientific jargon of Van Wyck Brooks; and the affectations of Van Vechten. Sentimental violence and overuse of such words as "devastating" and "poignant" are charged against Ben Hecht, Hutchinson, Walpole, and Hergesheimer.

SHERWOOD ANDERSON

—"*A prose-writer who dares to use the devices of the poet.*"

Mr. Beach finds Gamaliel Bradford too serious minded and turns for lightness of touch to Strunsky and Morley. In Anderson, Cabell, Mencken, and Sherman, he finds the supreme qualities of flavor and individuality, gusto, and precision. Kreymborg's style is "uniformly graceful, delicately tinted."

VAN VECHTEN

—"*Baedeker of the intelligentsia.*"

Mr. Beach has put to good use a conception of the genuine critical spirit characterized by candor and tolerance. He admits that he has been denied that arrogance which enables a critic to tell at a glance whether or not a writer is one of the immortals. First-rate prose he finds most frequently in the unpretentious styles that slip in between rigid categories.

You will want to read this book for the vigor of its outlook upon American prose and for its timely comment on some of the most interesting figures in modern literature.

H. L. Mencken says in the *American Mercury:* "This is perhaps the first book, written by an American, in which precept is backed up by practice. Mr. Beach writes very effectively, and has much of interest to say. His judgments on the writing of Dreiser, Anderson, Van Vechten and other living Americans are well-informed and plausible." *THE OUTLOOK FOR AMERICAN PROSE.* By Joseph Warren Beach. *$2.50, postpaid $2.60.*

* * *

New Version of the Psalms

For a long time we have needed a translation of the Book of Psalms into the language of our day—a translation that would give the modern reader new insight into the classical rendering of the King James Version, and enable him to see in the Psalms the meaning they originally had. Such a translation is the new version by J. M. Powis Smith, which removes the stumbling-blocks of a centuries-old vocabulary, and divests the verses of unwarranted meanings which a succession of early translators read into them. This version is based upon the official Hebrew text, corrected and emended in accordance with the findings of present-day scholarship.

Dr. Smith expresses at the outset his admiration for the King James Version of the Psalms as "a masterpiece of English literature, unrivalled in beauty," and disclaims any attempt to supplant it with his own version. His purpose is rather to express, as completely and as accurately as the limitations of language permit, the thought and feeling of the original; and to incorporate the scholarship of recent decades, with its more thoroughgoing text-critical method and improved philological results. His aim has been at all times to create a clear and uncorrupted version in which the reader of today will be able to see unhampered the beauties and true meaning of the world's greatest hymnbook.

This translation is intended for the public rather than for technical study; it is not, however, an attempt to bring the Psalms down to the level of the mythical "man on the street." The Psalms are here reproduced in a language and style befitting their spirit and content.

While seeking to avoid a bald literalism, Dr. Smith has preferred to err on that side rather than upon the side of paraphrastic expansion. His aim being always accuracy of meaning, he has chosen not to take the liberties of paraphrastic rendering.

The translator brings to his task unusual qualifications. He is professor of Semitic languages and literatures in the University of Chicago, editor of the *American Journal of Semitic Languages and Literatures*, and one of the foremost Hebrew scholars in this country. He is the author of several well-known books on Old Testament subjects.

This version of the Psalms is the first step in the complete American translation of the Old Testament, upon which a committee of Hebrew scholars is now working and which will require a year for its completion.

In this rendering, the modern reader can now read the Psalms in the language of his own day, just as they were written centu-

Teaching Science in the Schools

By

ELLIOT R. DOWNING

Scientific study of science teaching has had some valuable results, and these Mr. Downing summarizes in this volume. Here is shown how the growing body of facts about the pedagogy of science, which have been ascertained by the experimental method, may be applied practically to the problems of the science teacher.

This book describes the social and economic background of the science-teaching movement, the history of science teaching in our elementary and secondary schools, present conditions in science teaching, and the aims held.

From this point Mr. Downing takes up the principles of selection and organization of science materials, and actual methods of instruction—by book, lecture-demonstration, and laboratory. There is specific information on notebooks and drawings, field trips, testing results; and suggestions are made for a complete science library in the school.

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Brains of Rats and Men

That man's brain has been slowly developed from other kinds of animal brain structures, that human behavior patterns and the noblest human faculties are functions of man's peculiar protoplasmic organization—to many these still seem difficult statements to accept. Their truth, however, is further demonstrated by C. Judson Herrick in *Brains of Rats and Men*, his new book on the origin and biological significance of the cerebral cortex. It is a volume that belongs to that rare class of scientific works of genuine literary merit, in which Mr. Herrick traces the evolution of this amazingly complex organ from fishes to men, and follows step by step the elaboration of its functions.

Objective behavior and subjective experience are here reformulated in biological terms. Mr. Herrick demonstrates incisively that the entire intellectual, emotional, and moral life of mankind can be explored as biological functions without loss of their supreme values as distinctively human attributes and without passing outside the realm of natural laws.

Others have tried to read human faculties backward into the lower animals. Mr. Herrick reverses the order and, beginning with the simplest structures prophetic of cerebral cortex, he reads this history through to its culmination in man. He outlines also the development of the thalamus and corpus striatum and their functional relations with the cortex.

He turns then to the mechanism of learning, centering the discussion about the brains of rats and men, the two species of mammals whose behavior patterns have been studied most intensively under conditions of laboratory control. Recent experiments upon learning in rats are summarized.

In considering the transition from brute to man, Mr. Herrick calls attention to the fact that the brain of man is more than twice as heavy as that of an ape of equal

body weight and that this increase is chiefly in the cerebral cortex. The complexity of the internal texture of the human cortex surpasses that of an ape in still larger measure.

This account of the cerebral cortex, its evolution and its functions, by one of America's foremost neurologists touches upon problems that are fundamental to all the sciences that take living things, and man in particular, as their province: biology, psychology, anthropology, the social sciences, education, medicine.

H. L. Mencken comments: "It is, perhaps, the best summary of the known facts about mental processes yet put into English." And *The New York World:* "Again and again he discounts with a cool saneness the verbosity of new schools of psychology and philosophy . . . . [it is] suited to any intelligent reader." *BRAINS OF RATS AND MEN.* By C. JUDSON HERRICK. *$3.00, postpaid $3.15.*

* * *

Mexico

Americans give their neighbor a great amount of attention but never, so the Mexicans say, are able to dispose of misconceptions about her. Two of our recent publications, *Some Mexican Problems* by Moises Saenz and Herbert I. Priestley, and *Aspects of Mexican Civilization* by José Vasconcelos and Manuel Gamio, represent the efforts of men who know the country at first hand to outline the true state of affairs at the present time.

Moises Saenz is a member of the Department of Education of Mexico. He gives an authoritative interpretation of the situation created by foreign, particularly American, investments in Mexico; discusses the Mexican laborer; and the progress in integrating Mexico through education. His outline of the program of the Mexican government will tend to correct the impression that the country is given over exclusively to revolutions and political intrigue.

Professor Priestley, of the University of California, author of *The Mexican Nation, a History*, is well qualified to discuss the cultural relations of Mexico and the United States, and the problems which have grown out of Mexico's efforts at rehabilitation. He shows the need for a general reconstruction of Mexican society and ex-

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Evolution, Genetics, and Eugenics

By

HORATIO HACKETT NEWMAN

Attendance at the Dayton trial as a witness for the defense has enabled Professor Newman to describe and interpret it in this new revised edition of his text. He brings the knowledge of the evolutionary biologist to bear upon the present anti-evolution campaign in the United States, and studies it historically, giving the facts about evolution needed for an intelligent attitude toward the controversies.

The discussion of mutation, linkage and crossing-over, inheritance of acquired characteristics, eugenics, and other topics has been brought completely up to date. Here in a single volume is a comprehensive treatment of all the important phases of evolutionary biology that takes account of recent developments.

Original material by Professor Newman weaves together a well-balanced selection of excerpts from such writers as Darwin, Weismann, Romanes, and Castle. This is an excellent text for survey courses in evolutionary biology and a clear treatment for the general reader.

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Brains of Rats and Men

By C. JUDSON HERRICK

That man's brain has been slowly developed out of the brain structures of the lower animals; that human behavior patterns and the noblest human faculties are functions of man's peculiar protoplasmic organization—to many these still seem difficult statements to accept. Their truth, however, is further demonstrated by C. Judson Herrick in this book on the origin and biological significance of the cerebral cortex.

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amines the working policies and constructive acts of the Mexican people and government. His account is neither a general apologia for the Mexican program nor a wholesale condemnation of it.

Mr. Vasconcelos and Mr. Gamio, both of the Department of Education of Mexico, have outlined Mexican civilization in both its Latin-American and Indian aspects. Mexico is "a country of caste and opposition of every sort, a country of worry and wonder . . . . the rhythm of its very life is the rhythm of contrast," says Mr. Vasconcelos. His essay is an interesting study in contrast.

Mr. Gamio discusses one of Mexico's greatest problems, that of incorporating the Indian in Mexican population. And he has outlined, in the interests of mutual understanding, the efforts of Mexico and the United States to educate one another. *SOME MEXICAN PROBLEMS.* By MOISES SAENZ AND HERBERT I. PRIESTLEY. *ASPECTS OF MEXICAN CIVILIZATION.* By JOSÉ VASCONCELOS AND MANUEL GAMIO. *Each $2.00, postpaid $2.10.*

* * *

George Eliot to James Joyce

"The novels of George Eliot," says Walter L. Myers in *The Later Realism*, "may be named as the first that are adequately representative of native British realism fully matured but not yet modified by French naturalism and later European influences." He traces the development in realistic characterization from George Eliot to the most recent writers of the realistic school.

The writers considered fall into three groups: first, Eliot and Meredith; then, with Hardy as a connecting link, follow Wells, Bennett, and Galsworthy; and finally, Dorothy Richardson, James Joyce, D. H. Lawrence, and May Sinclair.

Mr. Myers has pointed out that the more advanced realistic characterization permits an effect that may properly be called incongruous; that there has been an infusion of something mystical; and that closer attention is being given to personality.

The reader who wishes to keep up with recent developments in British fiction will find this book interesting. *THE LATER REALISM.* By WALTER L. MYERS. *$2.00, postpaid $2.10.*

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THE

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March 1927

COMPARATIVE STUDY OF SPERMOGONIA OF RUSTS OF ABIES

LILLIAN M. HUNTER

(WITH PLATES I–IV AND TWO FIGURES)

Introduction

Abies is attacked by a great number of heteroecious rusts. In every instance it is the O, I, or aecidial phase that occurs on the fir host. Table I shows all the rusts reported for various species of *Abies*, and the hosts of the II–III stage where known.

It is quite certain that there are other species on *Abies*, the connections of which have not yet been established. This is probable for various species of *Hyalopsora*, *Milesina*, and *Pucciniastrum*.

All of the rusts of *Abies* are of the peridermial type except *Melampsora americana* and *M. Abieti-Caprearum*. As a rule the peridermia on *Abies* are very similar, in fact so nearly alike that some of them have not been and perhaps cannot be distinguished specifically, or even generically. They are readily separated, especially when fresh, into two groups on the basis of color of the spores, white and yellow. Within these groups the form of the peridermia, their location, and the effect of the rust on the host are characteristic for a few species but not for the rest. Such features of the spores as size, markings, and thickness of the walls are of help, but to a limited degree. It is of little wonder, then, that some confusion has resulted. A striking example of this is afforded by PECK's *Peridermium balsameum*. FRASER (10), in the first successful attempt to

work out the life history of *P. balsameum*, linked it up with *Uredinopsis americana* (*U. mirabilis*), but in further experimentation with the fungus from other host sources he also linked it up success-

TABLE I

RUSTS WITH 0, I STAGE ON ABIES

Name of rust	II, III host
1.*Melampsora americana Arth	Salix
2.*Melampsorella Caryophyllacearum Schroet	Alsine, Arenaria, Cerastium, Malachium, Moehringia, and Stellaria
3. Melampsorella Symphyti Bubak	Symphytum
4.*Pucciniastrum Abieti-Chamaenerii Kleb	Epilobium angustifolium, E. Dodonaei, and E. latifolium
5.*Pucciniastrum Epilobii (Pers.) Otth	Epilobium adenocaulon, and other species of the subgenus Lysimachion
6. Pucciniastrum Circaeae (Thuem.) Speg	Circaea lutetiana, etc.
7.*Calyptospora Goeppertiana J. Kühn	Vaccinium (III only)
8.*Hyalopsora Aspidiotus (Pk.) P. Magn	Phegopteris Dryopteris and P. Robertiana
9. Peridermium ornamentale Arth	
10.*Milesina Kriegeriana P. Magn	Aspidium spinulosum, A. spinulosum var. dilatatum, and A. Filix-mas
11.*Milesina marginalis Faull & Watson	Aspidium marginale
12.*Milesina polypodophila (H. P. Bell) Faull	Pteris aquilina
13. Milesina Blechni Syd	Blechnum spicant
14.*Uredinopsis Atkinsonii P. Magn	Aspidium Thelypteris and Asplenium Filix-femina
15.*Uredinopsis Phegopteridis Arth	Phegopteris Dryopteris
16.*Uredinopsis Osmundae Magn	Osmunda Claytoniana, O. cinnamomea, and O. regalis
17.*Uredinopsis americana Syd	Onoclea sensibilis and Woodwardia areolata
18.*Uredinopsis Struthiopteridis Störmer	Struthiopteris germanica and Woodwardia virginica
19. Uredinopsis Pteridis D. & H	Pteris aquilina pubescens
20. Peridermium rugosum H. S. Jackson	
21. Melampsora Abieti-Capraearum Tubeuf	Salix

* Found on *Abies balsamea*.

fully with *U. Struthiopteridis*, *U. Osmundae*, *U. Atkinsonii*, and *U. Phegopteridis* (11). FAULL, WATSON, and MOSS (9) repeated these tests with like results, and then extended the investigation to species of *Milesina*. As a result they have added to the list *Milesina Kriegeriana*, *M. marginalis*, and *M. polypodophila*. Thus PECK's name (*Peridermium balsameum*) has been doing duty, not for a single species, but for many species of two distinct genera; and it probably would have continued to do so if no cultural tests had been made. No one had recognized morphological differences.

With the white spored rusts of *Abies*, as with the yellow, however, the writer has found that the spermogonia commonly show very distinctive characters. It is the spermogonia accompanying the peridermia that exhibit the most distinctive taxonomic criteria. The purpose on which this paper is based, therefore, has been to make an intensive study from this point of view. The results have been generally satisfactory so far, except for the species of *Uredinopsis* other than *U. Pteridis*.

Material and methods

The material from which the sections of *Uredinopsis Pteridis* and *Peridermium rugosum* were made was obtained from the herbarium of the department of botany, University of Toronto, and was originally collected in the western states. The rest of the material, eleven species, was obtained in the Timagami Forest Reserve of Ontario, and with the exception of four species, *Melampsora americana*, *Melampsorella Caryophyllacearum*, *Hyalopsora Aspidiotus*, and *Milesina polypodophila*, was obtained from culture experiments. These were supplemented by field collections. All of the material from the Timagami Forest Reserve was found on leaves of *Abies balsamea*.

The work of collecting and the culture experiments were directed by Professor J. H. FAULL of the University of Toronto, who was assisted by Mr. G. D. DARKER, Mr. W. R. WATSON, and Dr. E. H. MOSS. The writer wishes particularly to express her thanks to Professor FAULL for the excellent and authentic material placed at her disposal. Appreciation is also extended to Dr. H. P. BELL for some of the field material.

The diseased leaves of *Abies balsamea* used for observation were

fixed in chromo-acetic, Flemming's fluid (weaker solution), Bouin's fluid, a weak formalin solution, and Carnoy's fluid. Flemming's fluid and chromo-acetic were both found to be excellent fixatives.

The material, after being passed through the usual grades of alcohol, was cleared in chloroform or cedar oil before being imbedded in paraffin. The leaves cleared in cedar oil cut more easily than those cleared in chloroform. One lot of material of *Hyalopsora Aspidiotus* was treated in a 50 per cent aqueous solution of eau de Javelle for 3–5 hours before being passed through the different grades of alcohol. This treatment proved to have a softening effect, so that the older leaves on which this rust occurs cut better than those subjected to no special treatment, even when cleared in chloroform rather than cedar oil. After using eau de Javelle, the staining properties of the leaf seemed to be altered, so that after being stained with safranin alone the section had a yellow tinge. This, however, was not objectionable.

All material was imbedded in paraffin of 54°, 57°, or 58° C. melting point. No injury to the fungus or leaf tissue was found to occur when paraffin of a higher melting point (57°–58° C.) was used; and better sections were obtained with it, especially in the case of rusts that occur on the older leaves of *Abies balsamea*. Both longitudinal and transverse sections were made. Those studied were 4–7 μ in thickness. All drawings of spermogonia were made from transverse sections excepting in the case of *Melampsorella Caryophyllacearum*, in which the most satisfactory sections were longitudinal ones; this is because very often the spermogonia occur singly at the very tip of the leaf.

The various stains used were safranin alone, safranin in combination with Delafield's haematoxylin, light green DLI, light green NL–3, or gentian violet; also iron alum haematoxylin alone and in combination with light green DLI. The most successful results were obtained by double staining with safranin and light green DLI or light green NL–3.

A weak aqueous stain of safranin (about 1 cc. of 1 per cent solution in 45 cc. of water) proved most effective. The light green DLI used was a 2 per cent clove oil solution, while that of the light green NL-3 was a 0.25 per cent one. The stain light green DLI was one

of a lot received from Dr. CONN, Chairman of the Biological Stain Commission, Geneva, New York, to be tested. Light green NL-3 was also obtained from Dr. CONN. The sections were left in the safranin solution over night. Before staining with light green, the slides bearing the sections were carried up through aqueous alcoholic solutions and some of the safranin was extracted. Care was taken not to remove too much safranin, since light green is acid in reaction and extracts this red stain somewhat rapidly. Before counter staining with light green, the sections still retained the safranin throughout all the tissues. Not more than two or three slides at most were carried up through the alcoholic solutions at one time. After reaching absolute alcohol the slides were removed one at a time, and the sections were stained in the light green clove oil solution, which was

Description

The spermogonia described belong to the following species:

1. Melampsora americana
2. Melampsorella Caryophyllaceae-rum
3. Pucciniastrum Epilobii
4. Calyptospora Goeppertiana
5. Hyalopsora Aspidiotus
6. Milesina Kriegeriana
7. Milesina marginalis
8. Milesina polypodophila
9. Uredinopsis Atkinsonii
10. Uredinopsis Phegopteridis
11. Uredinopsis Osmundae
12. Uredinopsis Pteridis
13. Peridermium rugosum

applied by means of a pipette. The light green was allowed to remain from 30 seconds to a minute on the slide, after which the sections were washed in pure clove oil and the usual procedure followed.

The amount of safranin extracted before applying the light green had to be determined by experience. If too much safranin is left in, the light green is not so effective in staining; and if too much safranin is extracted, the light green stains the section so completely that one does not get good differentiation. The cuticle on the leaf is more or less indifferent to either stain, and if it retains any at all it is a faint trace of safranin. The bast of the leaf and all of the cellulose walls stain green, while the wood retains the safranin. The intermediate epidermal layer stains with safranin, while the inner epidermal cell wall stains green. All fat globules and starch bodies stain red. Chloroplastids stain either green or red, depending upon the amount of safranin extracted before the addition of the light green. The walls

of the spermatophores usually stain green, while the contents of the mycelium are influenced by the red stain. The walls at the base of the spermatophores of the spermogonium often stain red. All nuclei stain red. The mycelium found in the intercellular and air spaces is usually green. Very often the combination of the red and green stain in the fungus gives a violet effect.

1. *Melampsora americana* (fig. 1).—The spermogonia occur on balsam leaves of the current season. They are small and numerous. FRASER (10), who studied this rust under the name *M. arctica* Rostr., reports them as hypophyllous. The writer finds that this is usually true and reports only one exception. Among numerous sections only one spermogonium was found on the upper surface of the leaf. The spermogonia extend well into the mesophyll and may be raised at either side less than one-third of their height above the neighboring epidermis. The subepidermal cells below the spermogonium are somewhat collapsed. During the development of the spermogonium there is much breaking down of the host cells. Sometimes subepidermal cells at the base of the spermogonium show indications of deterioration.

It may be noted here that LUDWIG (12) states that the spermogonia of this rust are subcuticular, but after careful examination the writer finds that they are subepidermal. The epidermal cells are attacked by the fungus and are more or less broken down. The entrance of the parasite to the epidermal cells, however, is made into the inner wall and not between the cuticle and the intermediate epidermal wall, nor between the secondary layer and the inner wall of the epidermal cell. The cuticle, the secondary layer, and the outer side of the inner wall of the epidermis remain over the spermogonium, and sometimes the entire epidermal cell as in the upper right of the spermogonium shown in fig. 1. An epidermal cell at the upper left of the spermogonium is invaded by a spermatophore. The lower wall is broken down but the upper wall is intact. The cutinized parts of the guard cells remain in the upper central part of the spermogonium, and at their left is a collapsed epidermal cell. The darkened areas at the base of the spermogonium may be the remains of collapsed subepidermal cells.

The spermatophores which make up the body of the spermo-

gonium arise from a mat of interwoven mycelium at the base of the spermogonium, and are directed toward an opening in the epidermis. The spermatophores are more or less radially arranged. They have septa which mark off uninucleate cells.

The spermogonia are more or less elliptical in section, and may or may not have a central depression in the outer side. They measure 92–154 μ broad by 42–67 μ high, and average 117 μ broad by 58 μ high. The number of mature spermogonia measured was 32.

The opening through which the spermatia pass is a slit in the epidermis or an opening between the guard cells. It is usually centrally placed, but may occur a little to one side of the center. It measures 5–8 by 40–50 μ. The long direction is parallel to the long axis of the leaf.

The spermatia are small, catenulate, oblong, and measure approximately 1–1.5 by 3.2–4.5 μ. Measurements were made by the writer from prepared sections, and also by Mr. G. D. DARKER from fresh material in the field.

2. *Melampsorella Caryophyllacearum* (figs. 2–5).—The spermogonia occur on balsam leaves of the current season. They are amphigenous, numerous, and are easily distinguishable, even without a hand lens. They appear as small, raised, round, orange spots, discrete or continuous. They are often found singly on the very tip of the leaf, but this feature is not essentially characteristic. The spermogonia are subcuticular and hemispherical, flattened in section. The mature spermogonium is characterized by a mat of closely interwoven hyphae at its base, from which the somewhat tapering spermatophores branch and extend outward toward a fairly centrally placed opening in the overlying cuticle. The material showed several stages in the development of the spermogonium.

Fig. 2 shows a very early stage. Here several strands of the septate mycelium are seen advancing through air spaces, over and between host cell walls, toward the epidermal layer. The hyphae separate the epidermal cell walls and pass between or over them and ultimately separate the cuticle from the epidermal wall. A later stage (fig. 3) shows many threads pushing along between the walls of the epidermal cells and forming a young spermogonium. There are small spaces between and above the young spermatophores. These

are filled with a substance which is probably a more or less gelatinous fluid.

A spermogonium of more advanced stage is seen in fig. 4. The tapering spermatophores advance more or less radially from enlarged basal cells toward the cuticle. Some spermatia have already formed, and are seen coming off in chains. The cuticle is unbroken and the space between it and the spermatophores is filled with a green staining substance, which is perhaps a gelatinous fluid. This fluid by pressure assists in opening the slit in the cuticle through which the spermatia emerge. In the mature spermogonium (fig. 5) the cuticle is broken and this gelatinous fluid has disappeared. The spermatophores branch from enlarged basal cells which form a mat at the base of the spermogonium. The spermatophores are septate and each cell is uninucleate. The radial arrangement of the spermatophores is not so pronounced as in the earlier stages (fig. 4). In fig. 5 the spermatophores have assumed a more erect position. Spermatia are being formed freely and are catenulate.

The spermogonia measure 99–317 μ broad by 27–59 μ high; the average measurements are 184 μ broad by 38 μ high. A total of 72 mature spermogonia was measured. ARTHUR (**2**) states that the spermogonia of *Melampsorella elatina* (Alb. & Schw.) Arth. (*M. Caryophyllacearum*) measure 100–130 μ broad by 40–50 μ high.

He describes the spermogonia as epiphyllous, few, and inconspicuous. This is not in agreement with the writer's findings, but ARTHUR'S statement that ostiolar filaments are not present is confirmed.

DE BARY (**7**) describes the spermogonia as both epiphyllous and hypophyllous, but more frequently the former. He also describes tender peripheral paraphyses as a feature of the spermogonium. The opening in the cuticle through which the spermatia emerge may be a slit or a wide opening. Usually, upon breaking the cuticle flies back and leaves most of the upper surface of the spermogonium exposed. The spermatia are oblong in shape (fig. 5), and measure 1.9–3.5 by 3.9–4.9 μ.

3. *Pucciniastrum Epilobii* (fig. 6).—The spermogonia occur on leaves of the current season. They are very small, raised, subcuticular, irregularly scattered, not conspicuous but easily seen with a

hand lens. A thin layer of the intermediate epidermal wall remains under the cuticle over the spermogonium. This is unlike the subcuticular condition in *Melampsorella Caryophyllacearum*, where the spermogonia are developed on very young leaves in the bud before the intermediate epidermal wall forms. The spermogonia are hypophyllous and in section appear hemispherical, flattened. The spermatophores are septate and each cell is uninucleate. They originate from a mat of mycelium at the base of the spermogonium, and are directed toward a centrally placed pore in the cuticle.

The epidermal cells at the base of the spermogonia are separated by intervening hyphae. With this exception, these epidermal cells are usually quite normal in appearance. Occasionally they may be pressed out of shape by pressure from the mycelium which separates them as it advances to form the spermogonium.

The spermogonia measure 62–137 μ broad by 15–33 μ high. The average measurements of 29 spermogonia are 84 μ broad by 20 μ high. Measurements of the spermogonia of *Pucciniastrum pustulatum* (Pers.) Diet. given by BELL (**6**) are 50–110 μ broad by 20–30 μ high; but as BELL made no distinction between *P. Abieti-Chamaenerii* and *P. Epilobii*, and his material was collected in the field, it is not certain with just which species of *Pucciniastrum* he worked.

The spermatia are catenulate. They are elongate and oval in shape, measuring 1.6 by 3.3 μ. Fig. 6 shows a number of spermatia in section which have been exuded from the spermogonia. The opening in the cuticle through which the spermatia are discharged is a long oval pore measuring 13–27 by 30–75 μ. It is somewhat centrally placed. The long direction of the opening is parallel to the long axis of the leaf. Occasionally half of the upper surface of the spermogonium is exposed. One opening was found to measure 43 by 95 μ.

4. *Calyptospora Goeppertiana* (fig. 7).—The spermogonia occur on leaves of the current season. They are small and very inconspicuous, indistinctly visible with a hand lens (10×), very numerous, subcuticular, and hypophyllous. They are low, and hemispherical to conoidal in shape. The spermatophores arise from enlarged hyphal cells at the base of the spermogonium. They are more or less radially arranged and point toward the upper center of the spermogonium. They are septate and the cells are uninucleate. The cuticle

over the great majority of spermogonia remains unbroken, but the spermatophores are formed and the arrangement of nuclei in them is suggestive of catenulate spore formation. No bodies which can definitely be described as spermatia were found, however, even in spermogonia where the cuticle was ruptured. Sometimes the cavity above the spermatophores is filled with irregular dark staining bodies which may be degenerate spermatia.

The epidermal cells are present at the base of the spermogonium. Sometimes they are depressed. They may be fairly normal in appearance, but again they may be elongated or crushed by the hyphae which pass between them to form the spermogonium.

The spermogonia measure 42–137 μ broad by 13–30 μ high. The average measurements are 73 μ broad by 21 μ high. The number of spermogonia measured was 105. ARTHUR (4) states that the spermogonia measure 80–140 μ broad by 25–30 μ high. These measurements correspond somewhat closely with those just given.

ARTHUR (4) states that the spermogonia are epiphyllous and few. This is not in agreement with the writer's conclusions, after thorough examination of authentic material obtained from various culture experiments as already described. As stated, the spermogonia are hypophyllous and numerous. BELL states that he found spermogonia of *Calyptospora Goeppertiana* (*C. columnaris* (A. & S.) Kühn), but he does not describe them. ADAMS (1) describes *C. columnaris* as having the stages O, I, but gives no description of the O stage.

Both Dr. E. H. MOSS and Mr. W. R. WATSON, after careful examination of fresh material of infected leaves which bore both spermogonia and mature aecidia, were unable to find any spermatia. As stated previously, measurements were made of median sections of 105 spermogonia of *C. Goeppertiana*. Many more spermogonia were examined which were considered immature, and among all of these only twelve were found to have a ruptured cuticle. In a few cases a mass of dark staining substance of indeterminable composition was found just above the upper center of the spermogonium, but even this seemed to be inclosed by a thin hyaline layer which may be a continuation of the cuticle.

There is evidence then that the spermogonia of this species are abortive. DODGE (8) describes vestigial or abortive spermogonia in

the pine rust, *Gallowaya pinicola* Arth. He states that host tissues above the spermogonia are not fully ruptured, and that spermatia are seldom formed. Here we have a parallel case to that of *Calyptospora Goeppertiana*. In the pine rust, however, the spermogonia are few in number, while in the balsam rust they are numerous. It is interesting to note that since it has been definitely ascertained that *C. Goeppertiana* bears spermogonia, the only remaining feature that separates *Thecopsora* from *Calyptospora* is that the latter lacks the uredinal stage.

5. *Hyalopsora Aspidiotus* (fig. 12).—The spermogonia occur on leaves of *Abies balsamea* of the second season. They are hypophyllous, and conspicuous as round, yellow, slightly raised spots. They are subepidermal, extending from the epidermis well into the mesophyll. There is a deep mass of interwoven mycelium separating the mesophyll cells below the base of the spermogonium. This feature is much more pronounced in this species than in any of the others studied. It is characteristic of *Hyalopsora Aspidiotus*. The base of the spermogonium itself consists of a mat of enlarged hyphal threads. It is from this mat that the spermatophores which make up the body of the spermogonium proceed. The spermatophores arise singly or branch from the intertwined mycelium which forms the mat at the base of the spermogonium. They are arranged in more or less radial lines directed to a fairly central opening in the epidermis, through which the spermatia are discharged. Septa occur in the spermatophores and mark off uninucleate cells. The spermogonia in section are more or less oval or lens-shaped, and are much flattened. The spermogonia measured were 25 in number. They are very much longer than they are deep, measuring 311–496 μ broad by 86–117 μ high. They are rarely less than 390 μ broad. The average measurements are 432 μ broad by 102 μ high. These measurements correspond closely with those made by BELL. He gives the limits 400–500 μ broad by 90–120 μ deep.

MAYOR (13) describes what appear to be the spermogonia of this or a related form on *Abies pectinata*. His measurements for the spermogonia are 300–360 μ broad by 150–210 μ high. These therefore are not so broad and are deeper than those recorded by BELL or by the writer. If the mat or weft of mycelium at the base of the

spermogonium is included by MAYOR in his results, it brings his measurements nearer to ours. The spermatia are described by MAYOR as spherical, and having an average diameter of 3 μ. These measurements are not in agreement with those made by the writer.

Spermatia are formed catenulately (text fig. 1). They are oblong not round, comparatively large, and measure approximately 2.4–3.9 by 5.1–8.7 μ. Measurements made by Mr. G. D. DARKER from fresh material obtained from culture experiments in the field are 2.4–3 by 5.1–8.7 μ.

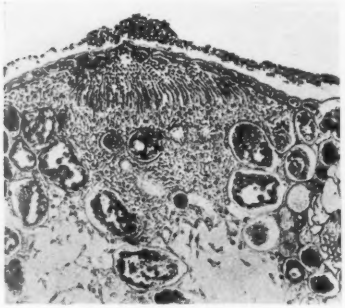

FIG. 1.—Photomicrograph of median vertical section of spermogonium of *Hyalopsora Aspidiotus*, from transverse section of leaf of *Abies balsamea;* ×200.

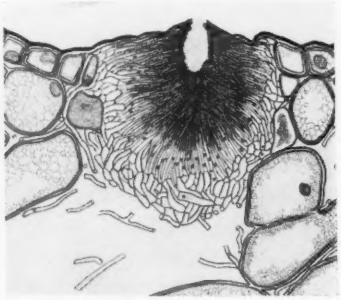

FIG. 2.—Photomicrograph of median vertical section of spermogonium of *Uredinopsis Pteridis*, from transverse section of leaf of *Abies grandis;* ×400.

The spermatia escape through a somewhat centrally placed opening in the epidermis. This may be made by a break in the epidermis or by means of a stoma, the guard cells of which are always abnormal. The opening takes the form of a slit, the long direction of which is parallel to the long axis of the leaf. It may measure 4–16.7 μ wide by 47–204 μ long. The slit lengthens as the spermogonium matures. Text fig. 1 shows a spermogonium with numerous spermatia and the slit in the epidermis through which they are discharged.

6. *Milesina Kriegeriana* (fig. 9).—The spermogonia are found on leaves of the current season. They are inconspicuous, but can be detected by means of a hand lens as tiny spots on the blanched leaves on which they occur. They are hypophyllous and occur very

abundantly. Sometimes as many as four spermogonia are found in a row in a transverse section of an infected leaf. These spermogonia occur more abundantly than in any other species of *Milesina*. They are imbedded in the mesophyll of the host leaf and are subcuticular. It is not the cuticle alone which remains over the spermogonium, however, but the intermediate granular layer of the epidermal wall immediately under the cuticle as well. The epidermal cells have disappeared, or sometimes some of them may be found crushed at the base of the spermogonium, as in fig. 9. The spermogonia rise very slightly above the neighboring epidermis. They depress the subepidermal cells beneath them. In section they are conspicuous and vary from hemispherical to subspherical in shape. Measurements made from prepared sections show a range of 84–137 μ broad by 59–84 μ high. An average of the 53 spermogonia measured is 110 μ broad by 71 μ high. Measurements made from prepared slides by Mr. WATSON are 80–140 μ broad by 60–90 μ high.

The spermatophores have septa which mark off uninucleate cells. The spermatophores arise from enlarged hyphal threads at the base of the spermogonium, and in more or less radial arrangement they advance toward a central opening in the cuticle through which the spermatia emerge. This opening takes the form of a slit, and measures 3.3–8.4 by 15–60 μ. The long direction of the slit is parallel to the long direction of the leaf.

The spermatia found in prepared sections have a range of measurements from 1.5–1.6 by 4.5–5 μ. Field measurements of spermatia made by Mr. WATSON are 1 by 4.6–7.4 μ.

7. *Milesina marginalis* (fig. 10).—The spermogonia occur on leaves of the current season. The leaves at the time of the appearance of the spermogonia are blanched. The spermogonia are inconspicuous but can be detected easily with a hand lens. They are amphigenous, but are found most frequently on the lower surface of the leaf, less frequently on the upper surface, and occasionally upon the side. The spermogonia are subcuticular, but the conditions are somewhat peculiar, as in *Milesina Kriegeriana*. The spermogonium lies under the combined cuticle and intermediate layer of the epidermal wall. The displaced epidermal cells have entirely disappeared; or sometimes, surrounded by the innermost wall, may be

found at the base of the spermogonium. The teethlike projections extending into the spermogonium from above are the remains of the granular layer which laterally separated the displaced epidermal cells from one another, and which are seen to be continuous with the intermediate layer referred to.

The spermogonium is very deeply seated in the mesophyll, and depresses the subepidermal cells beneath. Sometimes the subepidermal cells lying immediately beneath the spermogonium have collapsed. In section the spermogonia are conspicuous and vary from subspherical to almost spherical in shape. They are large, measuring 129–168 μ broad by 92–134 μ high. The average measurements of 50 spermogonia measured are 147 μ broad by 106 μ high. The ranges of measurements given by Mr. WATSON are 125–170 μ broad by 90–125 μ high.

The base of the spermogonium is made up of enlarged interwoven hyphae from which the spermatophores arise. The spermatophores are septate and each cell is uninucleate. They have a more or less radial arrangement, and are directed toward a central pore in the cuticle through which the spermatia emerge. The pore measures 1.7–5 by 20–50 μ. The long direction of this slitlike pore is parallel with the long axis of the leaf. The spermatia are catenulate. They are elongate and measure 1.6 by 5–8 μ. These measurements were made from prepared sections. Measurements made by Mr. WATSON from fresh material in the field are 1 by 4.6–9 μ.

8. *Milesina polypodophila* (fig. 11).—The spermogonia occur on leaves 2–8 years old. They are inconspicuous but can be seen distinctly with a hand lens. The affected needles are never blanched to nearly the same extent as those infected with *Milesina Kriegeriana* or *M. marginalis*. Infected portions are associated with a peculiar multiplication of twigs, producing a loose broom effect. The spermogonia are hypophyllous, very deeply seated in the mesophyll, and are subepidermal. In section they are very conspicuous and are nearly spherical, large, measuring 175–234 μ broad by 175–243 μ high. BELL gives the measurements 180–250 μ in diameter. On an average the 17 spermogonia measured by the writer are 199 μ broad by 212 μ high. The spermogonia are isolated. In the many sections examined there was only one instance where two spermogonia were found to be confluent.

There is some indication of more or less massed hyphal threads where an air space occurs below the spermogonium, but in most of the sections of *M. polypodophila* examined such a mass is entirely lacking. The base of the spermogonium itself is composed of enlarged hyphal threads interwoven to form a mat. It is from these that the septate spermatophores, more or less radially arranged, proceed to the upper middle of the spermogonium. The cells of the spermatophores are uninucleate. The spermatia are formed at the tips of the spermatophores. They are elongate and catenulate, and measure 1.7–2.5 by 5–7 μ. The spermatia are emitted through a pore which may be a slit in the epidermis or an opening through a stoma, the guard cells of which are abnormal. The opening is fairly centrally placed and measures 7–12 by 19–29 μ. The slit is not long, but its direction is parallel to the long axis of the leaf.

9. *Uredinopsis Atkinsonii* (fig. 8).—The spermogonia occur on leaves of the current season. They are hypophyllous and inconspicuous, and when mature extend somewhat deeply into the mesophyll. They are usually isolated, very seldom confluent. In section they are hemispherical and are usually quite flat on top, but may have a central depression. They are comparatively small, measuring 65–120 μ broad by 40–64 μ high. These measurements approximate those of *Milesina Kriegeriana*. On an average those of *Uredinopsis Atkinsonii* are smaller. The average measurements of 39 spermogonia are 95 μ broad by 53 μ high. They are subcuticular. The same conditions which exist in *Milesina Kriegeriana* are found in *Uredinopsis Atkinsonii*, however, namely, the combined cuticle and the intermediate layer of the outer epidermal wall remain over the spermogonium. At the upper right hand side of the spermogonium (fig. 8) the mycelium is seen separating an epidermal cell from the intermediate layer just referred to. In this figure also a spermogonium is shown in which the displaced epidermal cells have entirely disappeared. Occasionally one or two are found at the base of the spermogonium. The subepidermal cells below the spermogonium are depressed.

The spermatophores are arranged somewhat radially. They have septa which mark off uninucleate cells. The basal cells are long and tubular in shape. This is a very characteristic feature and is of great aid in distinguishing this species from *Milesina Kriegeriana*. The

opening in the cuticle through which the spermatia emerge is a lens-shaped pore or short slitlike opening which measures 4–12 μ wide by 15–25 μ long. The long direction is parallel to the long axis of the leaf.

The spermatia are small, oval, catenulate, and measure 1–3.3 by 2.5–5 μ. Measurements were made from dry and wet material as well as from sections.

The measurements of the spermogonia of *Uredinopsis* (*P. balsameum* Peck) given by BELL are 100–130 μ broad by 30–50 μ high. ARTHUR and KERN (5) state that the spermogonia are 100–130 μ broad by 35–50 μ high. These measurements correspond closely with those made by BELL. A short description of the spermogonia of *U. Phegopteridis* and *U. Osmundae* follows. They are so much like those of *U. Atkinsonii* that it is doubtful whether any real distinction can be recognized.

10. *Uredinopsis Phegopteridis*.—The description of the spermogonia of the species *U. Phegopteridis* is the same as that for *U. Atkinsonii*. The measurements of the spermogonia of *U. Phegopteridis* are 75–125 μ broad by 34–50 μ high. The average measurements of the 42 spermogonia measured are 95 μ broad by 48 μ high. The opening through which the spermatia emerge measures 1.6–11.6 by 15–30 μ. The spermatia measure 1.5–2 by 3.3–4.1 μ. These measurements were made from sectioned material only.

11. *Uredinopsis Osmundae*.—The description of the spermogonia of *Uredinopsis Osmundae* is similar to that of the other two species, *U. Atkinsonii* and *U. Phegopteridis*, only that the spermogonia of *U. Osmundae* were fewer in number for the number of sections cut than in the case of the others. The measurements for the spermogonia of *U. Osmundae* are 92–130 μ broad by 50–57 μ high. The average measurements are 112 μ broad by 52 μ high. This average is a little higher than that for the other two species described, but since only 8 spermogonia were measured, it is unfair to take these measurements as conclusive. The opening through which the spermatia emerge measures 3.3–20 by 15–85 μ. The spermatia measure 1.7 by 3.3 μ. Measurements were made from prepared sections.

12. *Uredinopsis Pteridis* (text fig. 2).—What is now generally considered as the O, I stage of this rust was described by ARTHUR

and KERN as *Peridermium pseudobalsameum* on materials collected by BLASDALE and HOWE from *Abies grandis*.

The spermogonia in the material sectioned were on leaves of *Abies grandis* of the second year. They are inconspicuous, numerous, hypophyllous, and subcuticular. The condition here is similar to that of *Milesina Kriegeriana*, *M. marginalis*, *Uredinopsis Atkinsonii*, *U. Phegopteridis*, and *U. Osmundae*, that is, the combined cuticle and intermediate layer of the outer epidermal wall remain over the spermogonium. The remains of epidermal cells are sometimes found at the base of the spermogonium. The spermogonia greatly depress the mesophyll tissue beneath.

The spermogonia of *U. Pteridis* are much larger than those of the other species of *Uredinopsis* described by the writer. The former measure 100–159 μ broad by 85–110 μ high. On an average they measure 127 μ broad by 98 μ high. These measurements were made from sections of the dried type material (collected by BLASDALE and HOWE, Eureka, California).

The base of the spermogonium consists of enlarged intertwined hyphal threads from which the spermatophores proceed in somewhat radial direction toward a fairly centrally placed pore in the cuticle. The spermatophores are septate, but it was impossible to find much detail because the dried tissue stained deeply. The pore in the cuticle measures 5–13.3 by 20–42 μ. The long direction of the slit is parallel to the long axis of the leaf. No clearly defined spermatia were seen, possibly because spore discharge had been completed in the material employed for histological examination.

Three other lots of material of *U. Pteridis* were sectioned and examined. Two of these were obtained from J. S. BOYCE, Washington State, and the other from H. S. JACKSON, Oregon. A summary of the measurements made from each of these follows.

(1) Spermogonia of material obtained from J. S. BOYCE measure 104–137 μ broad by 92–109 μ high. On an average they measure 121 μ broad by 102 μ high. Small bodies which are probably spermatia were found to measure 3.3 by 5 μ. The opening in the cuticle through which the spermatia emerge measures 7–17 by 20–40 μ.

(2) Spermogonia of the second lot of material obtained from the same source measure 134–154 μ broad by 67–92 μ high. On an av-

erage they measure 144 μ broad by 78 μ high. The opening in the cuticle measures 7–23 by 20–40 μ.

(3) Spermogonia of material obtained from H. S. JACKSON measure 139–184 μ broad by 75–87 μ high. On an average they measure 168 μ broad by 82 μ high. The opening in the cuticle through which the spermatia emerge measures 8–13 by 35–55 μ. In all cases this opening is a slit, the longitudinal direction of which is parallel to the long axis of the leaf.

From these measurements of the spermogonia, it will be noticed that those of the type material are somewhat vertically elongated in section, and that those of the lot listed under (1) most nearly approximate the type in measurement. The spermogonia under (2) and (3) in general are more horizontally elongated in section, and are less vertically elongated than those of the type material or of (1). These measurements indicate that the spermogonia under (2) and (3), although much larger than those given for *Peridermium balsameum*, are of that type, and stand out quite distinctly from those of the type material collected by BLASDALE and HOWE. Here the question may be raised as to whether or not all of the *U. Pteridis* material examined by the writer is authentic, or at least whether it all represents *P. pseudobalsameum*. There may be a confusion of species which have the O, I stage on *Abies grandis*.

The needles sectioned by the writer were all of the second year. In all of this material aecidia as well as spermogonia are borne. The aecidia are most certainly borne on leaves of the second year, but it is still to be determined whether or not the spermogonia appear on leaves of the first season and persist throughout the second season, or appear in the same year as the aecidia. Even though there is uncertainty as to the time of the appearance of the spermogonia in *U. Pteridis*, there is no reason for confusing it with such forms as *U. Atkinsonii*, *U. Phegopteridis*, or *U. Osmundae*, in which the spermogonia and the aecidia occur on the affected needles in the current season.

ARTHUR (4), who regards *Peridermium pseudobalsameum* Arthur & Kern as the O, I stage of *U. Pteridis*, describes the O stage of this rust, but does not state the age of the leaves on which the spermogonia occur. He gives the range of measurements of the spermogonia as 160–180 μ broad by 100–170 μ high. These measurements

are somewhat greater than those made by the writer, but they indicate that the spermogonia are vertically elongated in section. ARTHUR also states that the spermogonia are subcuticular. This is a correction of a statement made in an earlier publication (5), where it is stated that the spermogonia are subepidermal.

SCHMITZ (15) records a rust on *Abies amabilis* and one on *A. grandis*. The former case is doubtfully referred to as *P. pseudobalsameum* and in the latter identified as *P. balsameum;* the identifications were made by ARTHUR. SCHMITZ concludes that the difference between *P. pseudhbalsameum* and *P. balsameum* is but slight, being merely that the former has slightly larger and thicker walled spores. No cognizance is taken of the fact that the aecidia of the former are borne on needles of the second season, and that those of the latter are borne on leaves of the current season.

WEIR and HUBERT (17) state that "The close similarity of *P. pseudobalsameum* (D. & H.) Arth. with *P. balsameum* has led us to consider them here as one species, namely, *Peridermium balsameum.*" No reference in the literature previous to ARTHUR'S (4) in 1925 has been made to the age of the needles on which *P. pseudobalsameum* occurs. From WEIR and HUBERT'S text one would judge that they take for granted that this rust occurs on leaves of the current season, and that the name is based on a geographical factor; that is, *P. pseudobalsameum* is the name given as a rule to a rust on *Abies* in the west which corresponds to *P. balsameum* in the east.

These authors describe a rust alternating between *Abies grandis* and *Pteridium aquilinum* var. *lanuginosum* Bory (var. *pubescens* Under.), which, after comparative examination with several *Uredinopsis* species, they conclude to be *Uredinopsis Pteridis*. This rust bore aecidia on leaves of the second year, but no spermogonia were reported. No comparison of spermogonia, therefore, can be made here between this species and the type material of *P. pseudobalsameum* collected by BLASDALE and HOWE. It is fairly certain that the O, I stage of their rust is *P. pseudobalsameum*, although they assume that such is not the case. WEIR and HUBERT are in error, however, when they conclude that *P. pseudobalsameum* and *P. balsameum* may be considered as a single species, *P. balsameum*. The size and shape of the spermogonia alone demonstrate a specific distinction, even without consideration of the fact that the aecidia of *P. balsameum* are

borne on first year needles, while the aecidia of *P. pseudobalsameum* are borne on second year needles; therefore *P. pseudobalsameum* and *P. balsameum* cannot be used as synonymous terms. RHOADS, HEDGECOCK, BETHEL, and HARTLEY (14) have fallen into the same error as WEIR and HUBERT.

In their study of the life history of *U. Pteridis*, WEIR and HUBERT cultured only from *Abies* to *Pteris*. Apparently they made a guess as to the sequence of development in the opposite direction, stating that "The telial stage does not overwinter as is the common habit of such rusts. The needles of the fern must become infected during the same summer or fall in which the telia mature on the fern." The aecidia would complete their development in the following spring. They were unaware of the order of events in such a rust as *Hyalopsora Aspidiotus*, in which infection takes place in the spring on young needles, but the aecidia do not appear until the second spring after. In this latter species it happens that telia form, mature, and germinate on the fern host before the balsam needles are completely unfolded. Apparently, however, the same results would follow from overwintered teleutospores. If the teleutospores of *U. Pteridis* behave as do those of other species of *Uredinopsis* they surely overwinter, and it may be predicted that infection of *Abies* takes place when the needles are young. It is probable that there is a comparatively long period of incubation, the spermogonia developing toward the latter part of the first season and the aecidia at the beginning of the next.

13. *Peridermium rugosum*.—Some leaves of *Abies grandis* infected with *Peridermium rugosum* which were sent by H. S. JACKSON to Dr. FAULL were examined by the writer. Transverse sections 3 and 5 μ in thickness were made. The spermogonia were found to be hypophyllous, rather numerous, inconspicuous on the leaf surface, but conspicuous in section extending between the cells beneath and greatly depressing the tissues. These findings are in agreement with the description given by ARTHUR (3). In section the spermogonia are spherical rather than hemispheric or lenticular as described by ARTHUR. They are also subepidermal. The epidermal cells are often invaded by the mycelium, and the inner wall of some of the epidermal cells overlying the spermogonium may sometimes be broken down or digested. The measurements of the spermogonia are 144–

TABLE I: SUMMARY

SPERMOGONIA OF RUSTS OF ABIES

SPECIES	AGE OF LEAF	SHAPE (VERTICAL SECTION)	BREADTH (μ)	HEIGHT (μ)	POSITION	REMARKS	SIZE OF SPERMATIA (μ)
1. Melampsora americana	Current season	Elliptical, centrally depressed or not	92–154	42–67	Hypophyllous	Subepidermal	1–1.5 by 3.2–4.5
2. Melampsorella Caryophyllacearum	Current season	Hemispherical, flattened	99–317	27–59	Amphigenous	Subcuticular	1.9–3.5 by 3.9–4.9
3. Pucciniastrum Epilobii	Current season	Hemispherical, flattened	62–137	15–33	Hypophyllous	Subcuticular	1.6 by 3.3
4. Calyptospora Goeppertiana	Current season	Hemispherical to conoidal	42–137	13–30	Hypophyllous	Subcuticular	Aborted
5. Hyalopsora Aspidiotus	Two-three years	Lens-shaped, much flattened	311–496	86–117	Hypophyllous	Subepidermal	2.4–3.9 by 5.1–8.7
6. Milesina Kriegeriana	Current season	Hemispherical to subspherical	84–137	59–84	Hypophyllous	Subcuticular	1–1.6 by 4.5–7.4
7. Milesina marginalis	Current season	Subspherical to almost spherical	129–168	92–134	Amphigenous	Subcuticular	1–1.6 by 4.6–9
8. Milesina polypodophila	Two-eight years	Spherical	175–234	175–243	Hypophyllous	Subepidermal	1.7–2.5 by 5–7
9. Uredinopsis Atkinsonii	Current season	Hemispherical	65–120	40–64	Hypophyllous	Subcuticular	1–3.3 by 2.5–5
10. Uredinopsis Phegopteridis	Current season	Hemispherical	75–125	34–50	Hypophyllous	Subcuticular	1.5–2 by 3.3–4.1
11. Uredinopsis Osmundae	Current season	Hemispherical	92–130	50–57	Hypophyllous	Subcuticular	1.7 by 3.3
12. Uredinopsis Pteridis*	†	Hemispherical, vertically elongated	100–159	85–110	Hypophyllous	Subcuticular	‡

* On *Abies grandis;* all others from *A. balsamea.*

† Aecidia occur in second season; time of occurrence of spermogonia unknown.

‡ Probably discharged when material was collected.

223 μ broad by 144–200 μ high. The average of the 11 spermogonia measured is 170 by 169 μ. ARTHUR's (3) measurements are 140–170 μ broad by 120–160 μ high. These spermogonia correspond closely in their position in the leaf, and in their size, shape, and structure with those of *Milesina polypodophila* (fig. 11) found in *Abies balsamea*. Moreover, they also occur on needles older than those of the current season. The resemblance is so striking that the conclusion arrived at is that in all probability these two forms are the same species. This belief was further confirmed after critical comparative examination of the aecidiospores and the cells of the peridium. In markings and size those of *P. rugosum* closely tally with those of *Milesina polypodophila*. The spermatia of *P. rugosum* measure 2.2 by 4.5–7.6 μ. In size and shape they are much like those of *M. polypodophila*. Although the alternate host for *P. rugosum* has not yet been determined, it is reasonable to think that it may be found on some species of *Polypodium* in the west; and that *P. rugosum* is a species, if not identical with, at least closely related to *Milesina polypodophila*.

Summary

A summary of the preceding data is given in table I, page 21.

The writer wishes to express thanks to Dr. J. H. FAULL, under whose direction the work was carried on, and also wishes to express her appreciation of his contributions of material and his active interest and helpful assistance throughout the investigation.

DEPARTMENT OF BOTANY
UNIVERSITY OF TORONTO

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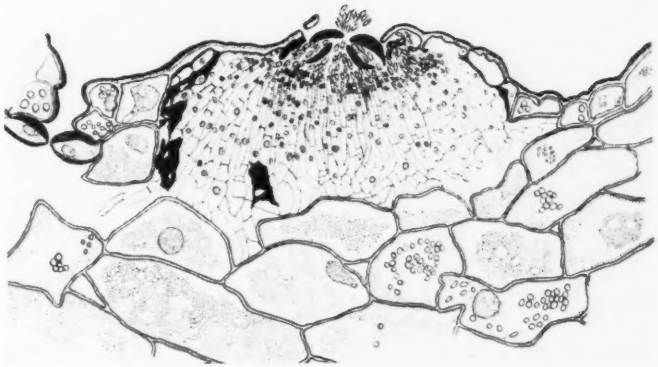

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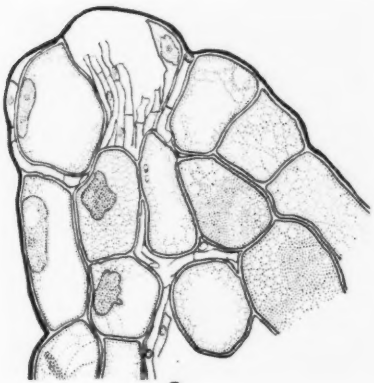

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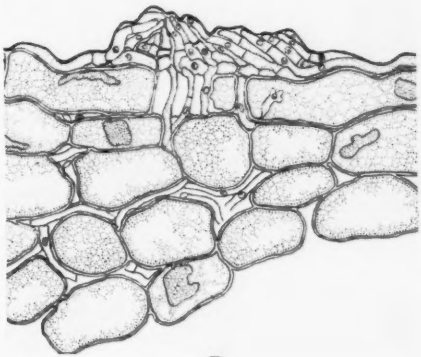

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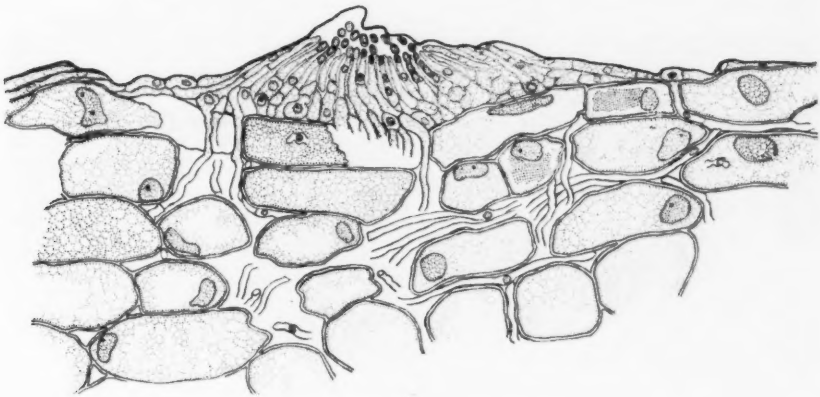

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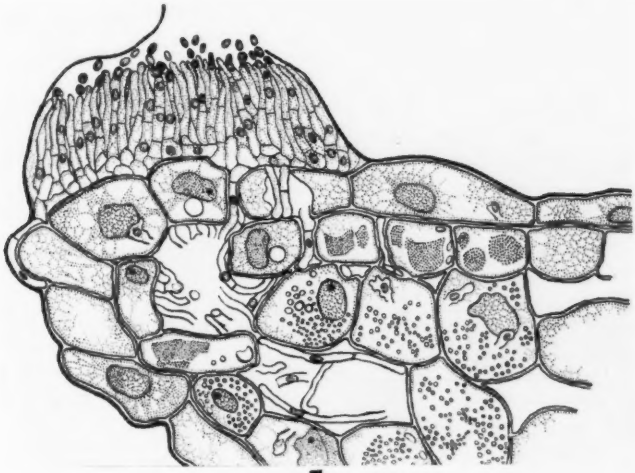
HUNTER on RUSTS OF ABIES



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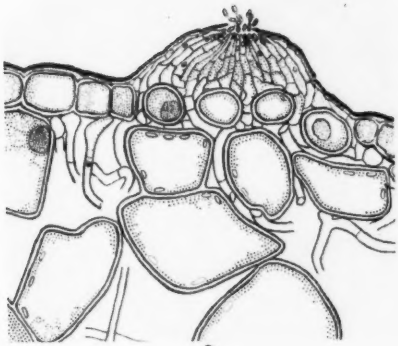

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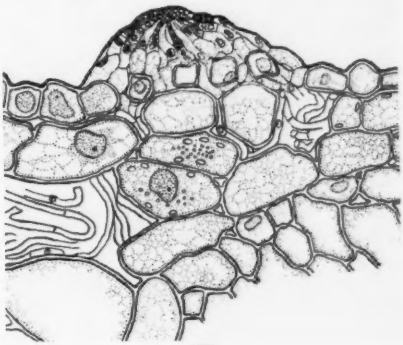

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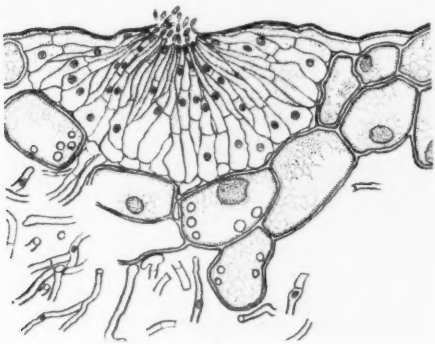

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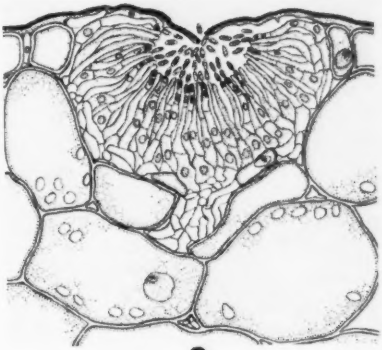

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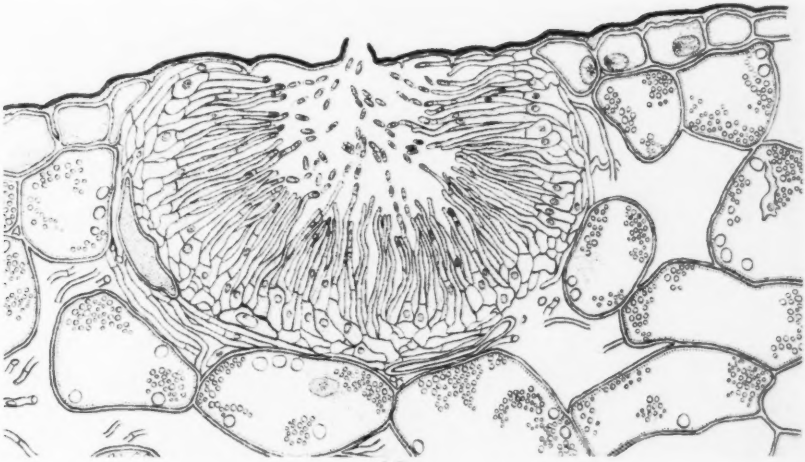

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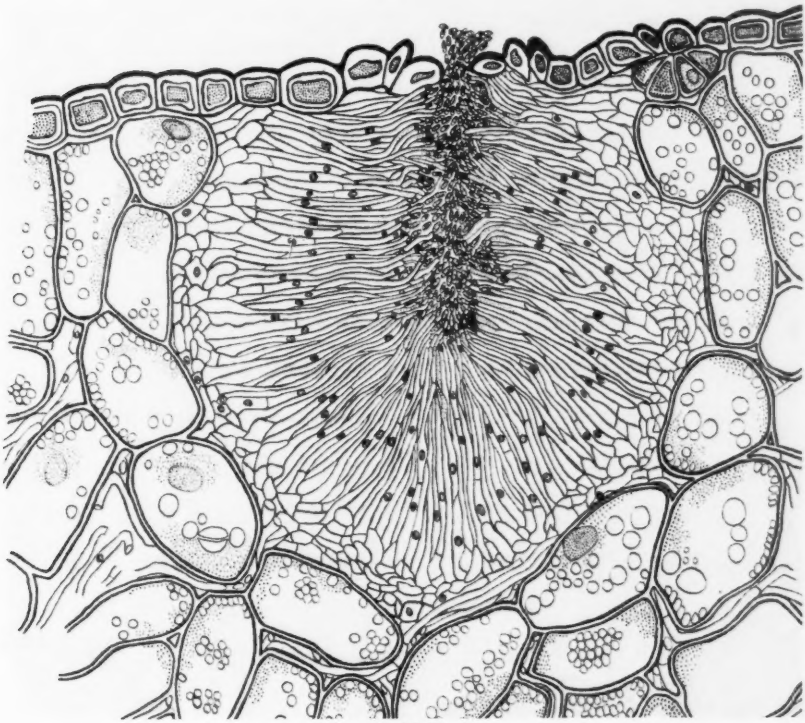

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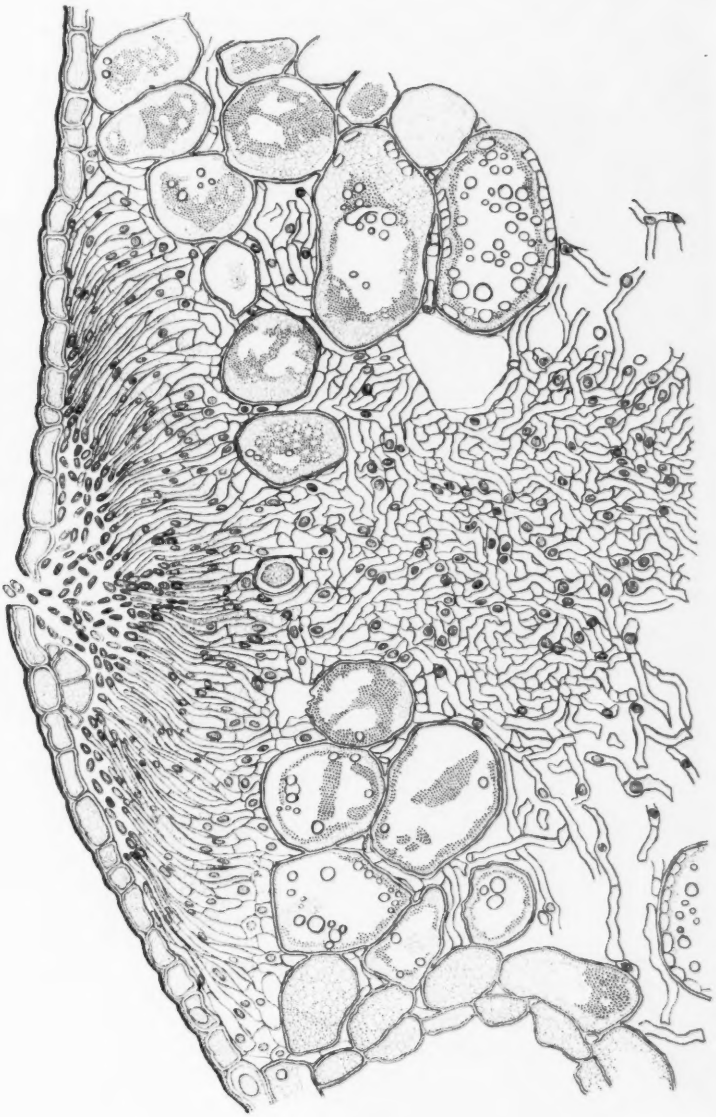

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EXPLANATION OF PLATES I–IV

FIG. 1.—Median vertical section of spermogonium of *Melampsora americana*, from transverse section of leaf of *Abies balsamea;* ×413.

FIG. 2.—Early stage in development of spermogonium of *Melampsorella Caryophyllacearum*, from longitudinal section of leaf of *Abies balsamea;* ×413.

FIG. 3.—Somewhat later stage in development of spermogonium of *Melampsorella Caryophyllacearum;* ×413.

FIG. 4.—Median vertical section of spermogonium of *Melampsorella Caryophyllacearum*, just before spore discharge takes place; ×413.

FIG. 5.—Median vertical section of fully mature and ruptured spermogonium of *Melampsorella Caryophyllacearum*, from longitudinal section of leaf of *Abies balsamea;* ×413.

FIG. 6.—Median vertical section of spermogonium of *Pucciniastrum Epilobii*, from transverse section of leaf of *Abies balsamea;* ×413.

FIG. 7.—Median vertical section of spermogonium of *Calyptospora Goeppertiana*, from transverse section of leaf of *Abies balsamea;* ×413.

FIG. 8.—Median vertical section of spermogonium of *Uredinopsis Atkinsonii*, from transverse section of leaf of *Abies balsamea;* ×420.

FIG. 9.—Median vertical section of spermogonium of *Milesina Kriegeriana*, from transverse section of leaf of *Abies balsamea;* ×413.

FIG. 10.—Median vertical section of spermogonium of *Milesina marginalis*, from transverse section of leaf of *Abies balsamea;* ×413.

FIG. 11.—Median vertical section of spermogonium of *Milesina polypodophila*, from transverse section of leaf of *Abies balsamea;* ×400.

FIG. 12.—Median vertical section of spermogonium of *Hyalopsora Aspidiotus*, from transverse section of leaf of *Abies balsamea;* 413.

SEASONAL VARIATION IN SPECIFIC CONDUCTIVITY OF WOOD IN TROPICAL PLANTS WITH REFERENCE TO LEAF FALL[1]

R. S. Inamdar and A. L. Shrivastava

(with seven figures)

Introduction and methods

The problem of leaf fall in the tropics is indissolubly connected with the general phenomenon of periodicity in plants. The complex nature of the latter phenomenon has so far eluded exact analysis of the factors concerned in the process. The investigator is at once faced with the difficulty of evaluating quantitatively the distinctive effects of internal factors in the plant and of the external environment. Is periodicity a phenomenon inherent in the living organism, irrespective of the external environment (**1, 5**), or is it introduced merely as an adaptation to the changing environmental factors? Even if the former view be accepted, the exact periods of rest and activity, with reference to any given set of functions, must have had some reference to the environmental factors for their origin. Cases where periods of rest and activity are changed by changing the habitat are not unknown (**2, 14**). On the other hand, there are plants which endeavor to retain their periods of rest and activity even in an environment where periodicity is not well marked (**14**). In such cases one can speak of the cumulative influence of the environment on the race being fixed in heredity as internal factors, or persisting as after effects. The organism might be plastic, in which case it will withstand the new environment with new adjustments and adaptations; otherwise it will not survive the change. The distinction between internal factors and the superficial effects of external factors is not always easy to understand. Individuals of the same species growing in an apparently similar habitat, or even different branches of the same plant, might shed their leaves at different periods of the year (**14**), as in *Ficus religiosa*. It would therefore be profitable to investigate the actual internal changes that take place during

[1] Contribution from the Department of Botany, Benares Hindu University.

the periods of rest and activity, instead of endeavoring to refer the phenomena to the causative internal or external factors. It is reasonable to expect some sequence in the internal changes leading to the final results, but until that sequence is well established, it is safe to speak of them as correlative changes, rather than as a sequence of cause and effect.

While the phenomenon of leaf fall in the temperate regions is commonly spoken of as a response to intense cold (**12**), that in the tropics is generally understood to be due to shortage of water supply (**14**). The effects of intense heat or insolation, however, are also to be reckoned with. The effects of each of these require careful analysis. In a place like Benares, leaf fall seems to be associated more with the driest period of the year, although this also happens to be the hottest period (April, May, and June). Trees which shed their leaves during winter are not uncommon in the area, but very few of them are entirely bare of leaves. Heat and light in this instance might be considered entirely as independent factors, or as ones that influence the phenomenon secondarily by increasing the rate of transpiratory activity, which appears to be more probable. It was therefore considered to be a matter of considerable interest to investigate whether there are any correlative internal changes in the plant during the time of leaf fall, influencing the supply of water to the transpiring leaves. With this object in view, the following experiments were conducted in Benares from April to November, 1923.

The supply of water to the leaves depends not merely on the external supply to the roots, but also on the capacity of the conducting tissues to carry water. In trees with their roots penetrating deep down in the soil, there is less likelihood of the external supply to the roots acting as a limiting factor. On the other hand, it might conceivably be argued that during the hottest period of the year the increase of temperature accelerates, if anything, the absorptive capacity of the roots, unless the soil temperature rises to a harmful extent. This latter possibility, however, is remote. If the phenomenon of leaf fall is to be associated with the supply of water to the transpiring leaves, therefore, our main consideration will have to be directed to the changes in the water conducting capacity of the vascular tissue.

A simple method to investigate the conducting capacity of the vascular tissue was devised by FARMER (4). He expresses his "specific conductivity" in terms of "specific volume," which he defines as the volume of water transmitted by a stem 15 cm. in length per sq. cm. of wood (in cross-section) under a definite pressure of water column. His method can conveniently be used for comparing the conducting capacity of the vascular tissue in different seasons of the year, on the assumption that all the water is transmitted through the wood. This method was therefore adopted in the course of the present investigation. It must be stated, however, that the specific conductivity does not necessarily bear a direct ratio to the absolute amount of water supplied to the leaves, unless another assumption is made, namely, that the water supply to the conducting elements is not limiting the rate. As already stated, this reservation does not affect the problem in the case of deeply rooted trees.

The apparatus adopted was more or less similar to the one used by FARMER (4). For the source of pure water supply for forcing water through the stem, a copper aspirator (filled with water comparatively free from dirt) was used instead of the direct supply from the water taps of the laboratory. The pressure of water column used by FARMER was equivalent to 30 cm. of mercury. This pressure could not be maintained in the present investigation, since the direct supply from the water taps contained many impurities which choked up the vessels. DIXON (3) has also found that for measuring the volume of water conducted through the stem under pressure, it is safer to adopt a lower pressure. The pressure that was given here to force the water through the stem amounted to 8.5 cm. of mercury column. This gave satisfactory results, and the readings remained constant from period to period (table I). Only those results which gave constant readings were taken into consideration.

The pieces of stem were prepared in the same way as described by FARMER. Prepared pieces were attached to the apparatus and the water was forced through them under pressure. The mean volume of water passed within a period of 15 minutes was measured as the absolute volume of water. A transverse section at the middle portion of the piece used was next taken, and the area of the wood was measured with the aid of a planimeter from camera lucida draw-

ings of the sections. The length of the piece of stem remaining constant always, the absolute volume divided by the area of the wood denoted the "specific conductivity"; or, in other words, the capacity of the wood to conduct water comparatively per given volume of the conducting elements, provided the supply of water is not limiting the rate of flow. Table I gives some preliminary readings taken from three portions (base, middle, and apex) of a branch of *Ficus religiosa*. Usually three or four readings of absolute volume were taken to ensure that the rate of flow through the stem remained constant during the period of observations.

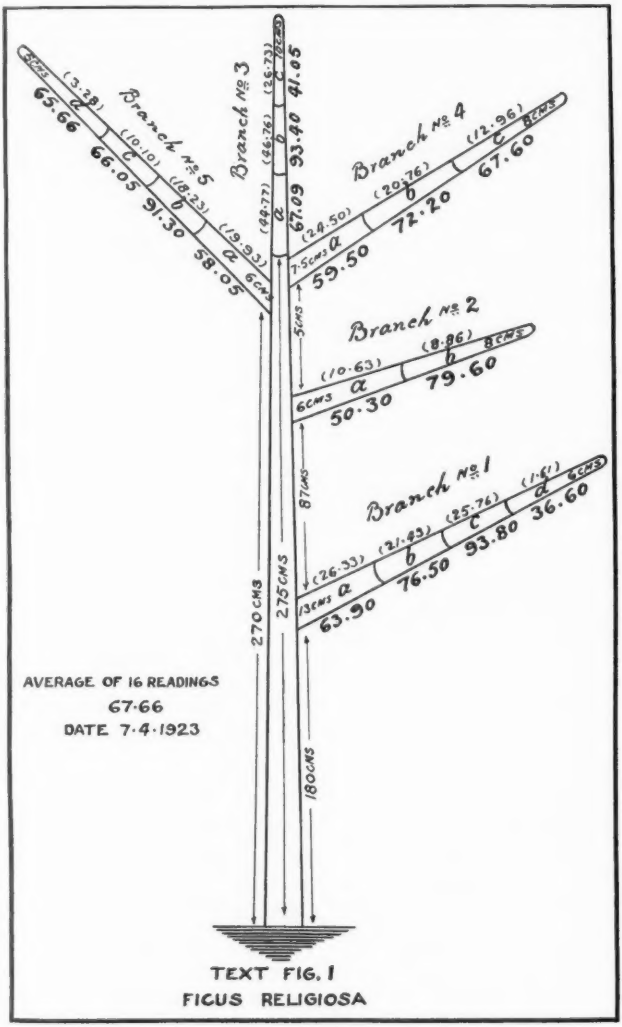
TABLE I

PRELIMINARY READINGS WITH FICUS RELIGIOSA; APRIL 11, 1923

PORTION OF BRANCH	ABSOLUTE VOLUME OF INDIVIDUAL READINGS (CC.)	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
(*a*) Basal.....	(1) 24.60 (2) 24.80 (3) 24.10	24.50	0.4147	59.50
(*b*) Middle....	(1) 21.00 (2) 20.90 (3) 20.40	20.76	0.2597	72.20
(*c*) Apical....	(1) 13.00 (2) 13.20 (3) 12.70	12.96	0.1915	67.60

Table I shows that the specific conductivity of the three portions of the branch varies considerably, a phenomenon which was also noticed by FARMER. In fact, the distinction which FARMER has drawn between trees of sympodial and monopodial habit of growth lies in the fact that in the former the specific conductivity falls off rapidly from the base of the growing shoot to the apex, while in the latter the difference is not so marked. This variation in the specific conductivity from different localities on the branch, from branch to branch placed at different levels on the tree, and from individuals to individuals, offers a serious difficulty in comparing the seasonal variations of the specific conductivity. It is not always safe to base the comparisons on averages, unless the number of observations is very great and representative of variations. For these reasons observa-

tions were made in several ways, as follows, to determine the specific conductivity comparatively in the leafy and leafless condition of the tree. Observations were made at the same time of the year



TEXT FIG. 1
FICUS RELIGIOSA

on different trees of a species, and on different branches of a tree, some having leaves still attached, others having no leaves, and still others showing newly developing leaves. Comparisons were also made between the specific conductivity of the wood from a number of observations at different seasons of the year, namely, once at the time of leaf fall, and again when new leaves were fully developed.

Preliminary results on Farmer's lines

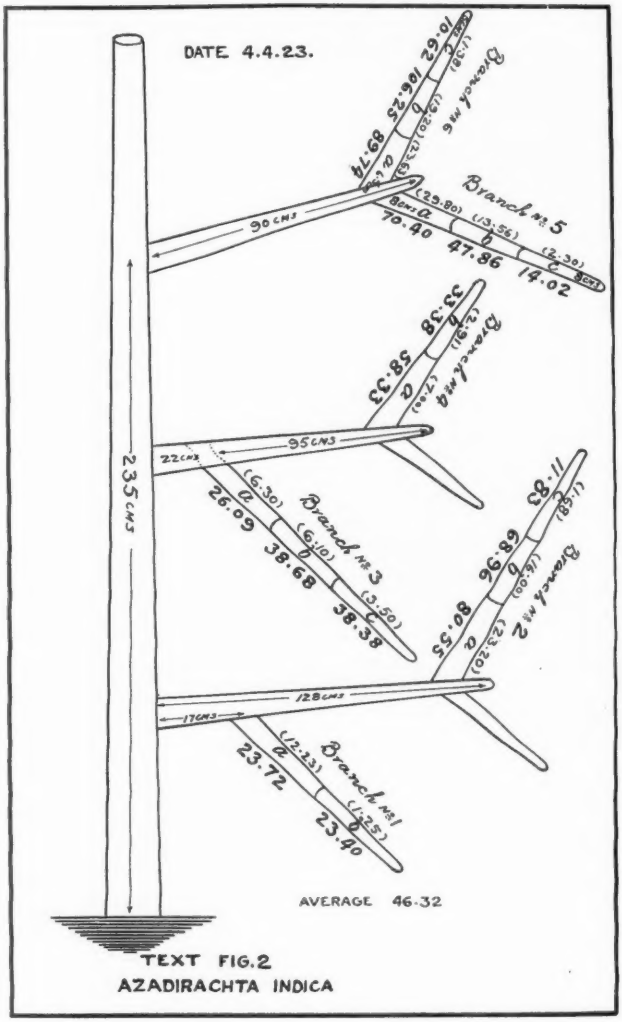
Some preliminary observations were made to confirm the distinctions drawn by FARMER between sympodial and monopodial growth, and between deciduous and evergreen trees. Although these observations have no reference to the problem of leaf fall, the results obtained are of sufficient importance to be recorded here, since no other work on similar lines appears to have been carried out on tropical plants.

DISTINCTION BETWEEN SYMPODIAL AND MONOPODIAL GROWTH

FARMER'S conclusions on plants of the temperate region have already been stated. The results obtained with *Ficus religiosa* and *Azadirachta indica* are described here as representatives of monopodial and sympodial growth respectively. A number of ultimate branchlets were chosen from each tree, and the change in the specific conductivity was measured on each branch from the base to the apex. Figs. 1 and 2 indicate respectively for the two plants the relative positions on the tree of the branchlets chosen for experiment, and of the different pieces cut from each branchlet. The branchlets are numbered serially in Arabic numerals, and the pieces from each branchlet are marked *a*, *b*, etc. The figures given in brackets indicate the absolute volume of water conducted by each piece; those given in bold type without the brackets represent the specific volume or the specific conductivity. The distances are marked in cm. The results are also given in tables II and III respectively.

The results of specific conductivity included in these tables and figures show that, in the normal growing shoots of sympodial habit (branches 2, 5, 6 in table III and fig. 2), the capacity for conducting water falls off rapidly from the base to the apex. The phenomenon is not so well marked in *Ficus religiosa* with a mono-

podial habit of growth. As FARMER observes, probably one of the main causes that lead to the dormancy or death of the top bud in sympodial growth is the failure of water supply to the growing



TEXT FIG. 2
AZADIRACHTA INDICA

region, thus necessitating the development of the adventitious buds. PALLADIN (11) also attributes the characteristic sympodial habit to the descending water current demonstrated by WIESNER (16). He

TABLE II

FICUS RELIGIOSA; APRIL 7, 1923

BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
1*a*	26.33	0.4116	63.90
1*b*	21.43	0.2798	76.50
1*c*	25.76	0.2745	93.80
1*d*	01.61	0.0439	36.60
2*a*	10.63	0.2115	50.30
2*b*	08.86	0.1113	79.60
3*a*	44.77	0.6675	67.09
3*b*	45.76	0.4900	93.40
3*c*	20.73	0.5050	41.05
4*a*	24.50	0.4147	59.50
4*b*	20.76	0.2597	72.20
4*c*	12.96	0.1915	67.60
5*a*	19.93	0.3433	58.05
5*b*	18.23	0.1995	91.30
5*c*	10.10	0.1529	66.05
5*d*	03.283	0.0500	65.66
	Average of readings 67.66		

TABLE III

AZADIRACHTA INDICA; APRIL 4, 1923

BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY	REMARKS
1*a*	2.23	0.0940	23.72	Branchlet from a thick and comparatively old branch; apical portion missing
1*b*	1.25	0.0531	23.40	
2*a*	23.20	0.2880	80.55	
2*b*	16.00	0.2320	68.96	
2*c*	1.68	0.1420	11.83	
3*a*	6.30	0.2414	26.09	
3*b*	6.10	0.1577	38.68	Branch injured at base
3*c*	3.50	0.09119	38.38	
4*a*	7.00	0.1200	58.33	Apical portion missing
4*b*	2.91	0.08717	33.38	
5*a*	29.80	0.4229	70.40	
5*b*	13.56	0.2833	47.86	
5*c*	2.30	0.1640	14.02	
6*a*	23.63	0.2633	89.74	
6*b*	19.20	0.1807	106.25	
6*c*	1.387	0.1306	10.62	
	Average of readings 46.32			

observes that, due to the early development of the leaves just beneath the terminal growing point, water is withdrawn by them from the terminal bud for purposes of transpiration, resulting in the death of the terminal bud. When such plants were cultivated in an atmosphere nearly saturated with water vapor, monopodial growth was the result. That deficiency of water should influence characteristic growth is no curious phenomenon, since water is an important constituent of protoplasm, and since turgor is a condition essential to growth.

Distinction between deciduous and evergreen trees

Farmer has drawn the conclusion that the average specific conductivity in a deciduous tree is generally higher than that in an evergreen. Although his observations, except in those cases where he has worked with the deciduous and evergreen species of the same genus, do not necessarily indicate that a deciduous tree growing under similar conditions of habitat indicates always a higher specific conductivity than an evergreen, he has been led to this general conclusion from a great number of observations made on the two types of plants. It was a matter of interest to investigate whether the differences noted by him were connected primarily with the relative

TABLE IV

Mangifera indica; August 30, 1923

Branch no. and portion of branch	Mean absolute volume (cc.)	Actual area of wood (sq. cm.)	Specific volume or specific conductivity
1*a*	13.73	0.2665	57.57
1*b*	9.83	0.2192	44.84
1*c*	2.45	0.0772	31.73
2*a*	13.60	0.1900	71.57
2*b*	5.30	0.1624	32.62
2*c*	1.116	0.0828	13.40
3*a*	14.65	0.2576	56.08
3*b*	6.03	0.2005	30.07
3*c*	0.683	0.0816	8.33
4*a*	7.90	0.2080	38.00
5*a*	18.83	0.3402	55.34
5*b*	7.90	0.2142	36.90
6*a*	6.20	0.1322	46.74
6*b*	1.50	0.0733	20.46
		Average of readings	38.83

demands on the water supply made by the two kinds of plants. The results obtained on an evergreen, *Mangifera indica* (table IV), were therefore compared with those of a few deciduous trees, the leaves of which varied in their transpiring capacity, inducing thus a variation in their demands on the water supply. As deciduous trees *Ficus*

TABLE V

PSIDIUM GUAVA TREE NO. 1

DATE	BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
June 2, 1923	1*a*	5.96	0.2553	23.34
	1*b*	4.55	0.1932	23.56
	1*c*	2.25	0.1168	19.26
	1*d*	0.45	0.0834	5.40
	2*a*	3.21	0.1908	16.82
	2*b*	2.80	0.1189	23.54
	2*c*	1.25	0.0645	19.38
	3*a*	6.96	0.2663	26.13
	3*b*	4.11	0.1964	20.92
	3*c*	2.16	0.1100	19.63
	4*a*	3.03	0.1701	17.81
	4*b*	2.00	0.1130	17.70
	4*c*	1.00	0.0591	16.95
		Average of readings		19.26
September 26, 1923	1*a*	3.00	0.1633	18.37
	1*b*	2.46	0.1437	17.05
	1*c*	1.48	0.1082	13.67
	2*a*	1.85	0.1645	10.94
	2*b*	1.08	0.0846	12.80
	2*c*	0.3525	0.0634	5.55
	3*a*	7.06	0.2576	27.01
	3*b*	4.56	0.2109	21.10
	3*c*	1.27	0.0863	14.71
	3*d*	0.385	0.0443	8.69
	4*a*	3.73	0.2224	16.77
	4*b*	3.73	0.1710	21.63
	4*c*	3.00	0.1740	17.24
	4*d*	0.40	0.0563	8.00
		Average of readings		15.25

religiosa (table II), *Azadirachta indica* (table III), and *Psidium guava* (table V) were used in the order of their transpiring capacities. The tables include a number of observations on different branches, and the averages are used for comparison.

It will be seen that the evergreen *Mangifera* has a lower average specific conductivity (38.83) than the deciduous *Ficus religiosa*

(67.66) or *Azadirachta indica* (46.32), but the specific conductivity of the deciduous *Psidium guava* (average varying from 15.25 to 19.26) is actually lower than that of the evergreen *Mangifera indica*. It may be noticed further that the variations in the specific conductivities of the deciduous *Ficus religiosa* and *Azadirachta indica* are in the same direction as their relative transpiring capacities. It may safely be concluded that the distinctions drawn by FARMER between the evergreens and deciduous trees relate primarily to the demand on the water supply made by the leaves for purposes of transpiration. In general, an evergreen may be expected to be more "xerophytic" in construction with reference to transpiration than a deciduous tree, with the consequent result that the specific conductivity in the former is in general lower than that in the latter.

Seasonal variations in specific conductivity with reference to leaf fall

OBSERVATIONS AT ABOUT THE SAME TIME OF YEAR DURING LEAF FALL

The variations in the specific conductivity of the wood with reference to leaf fall were tested in several ways. In the first series of observations, comparisons were made at about the same period of the year between individuals of the same species, and branches of the same tree, showing variations from the leafy to the leafless condition, some also showing development of new leaves in the latter condition. The species used for this series of observations was *Bauhinia variegata*, which sheds its leaves about the end of April, and remains in a leafless condition for only a short period of about one month at the most. In the first instance the averages from a number of results obtained on trees in different conditions are compared. Tree no. 1 contained only old leaves, tree no. 2 old and young leaves mixed together, and tree no. 4 only young leaves. The results are summarized in tables VI, VII, and VIII*a* respectively. The averages of specific conductivity show a regular gradation according to age, from 61.02 in tree no. 1 to 57.58 in tree no. 2 and 50.12 in tree no. 4. The specific conductivity reaches its maximum value just before leaf fall, and suddenly drops down immediately after leaf fall, especially when the young leaves come out as fully developed structures.

TABLE VI

BAUHINIA VARIEGATA TREE NO. 1, APRIL 17, 1923

TWIG NO.	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
1	5.43	0.2251	24.20
2	22.15	0.3300	67.10
3	16.06	0.1909	84.00
4	8.33	0.1887	44.15
5	12.26	0.1769	69.30
6	12.30	0.2183	56.30
7	11.65	0.2195	53.10
8	11.03	0.1896	59.80
9	14.30	0.2025	70.60
10	12.76	0.2079	60.00
11	6.63	0.1246	53.20
12	13.13	0.1671	78.50
13	14.46	0.2231	64.80
14	14.65	0.1918	76.30
15	11.80	0.1628	72.24
16	5.80	0.1533	37.80
17	11.23	0.1473	76.20
18	4.83	0.0949	50.90
			Average of readings 61.02

TABLE VII

BAUHINIA VARIEGATA TREE NO. 2

DATE	BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC CONDUCTIVITY OR SPECIFIC VOLUME
May 7, 1923	1*a*	7.40	0.1129	65.50
	1*b*	6.93	0.1073	64.50
	2*a*	7.50	0.1186	63.20
	3*a*	6.90	0.1201	57.40
	3*b*	9.50	0.1254	75.70
	4*a*	7.00	0.1500	46.60
				Average 62.15
May 22, 1923	1*a*	12.76	0.2060	59.50
	1*b*	7.70	0.1360	56.60
	2*a*	14.33	0.2278	62.90
	2*b*	9.36	0.2071	45.19
	3*a*	6.95	0.1917	36.50
	3*b*	12.03	0.1695	70.90
	3*c*	9.76	0.1518	64.60
				Average 56.58
	4	1.80	0.0358	50.20
	5	1.71	0.0366	46.50
				Average 48.35
				Average of readings 57.58

In the second set, detailed observations were made on tree no. 2 on different branches in different stages of growth. The observations on May 7, 1923 were made on branches which contained a large proportion of old leaves and a few young leaves; and those on

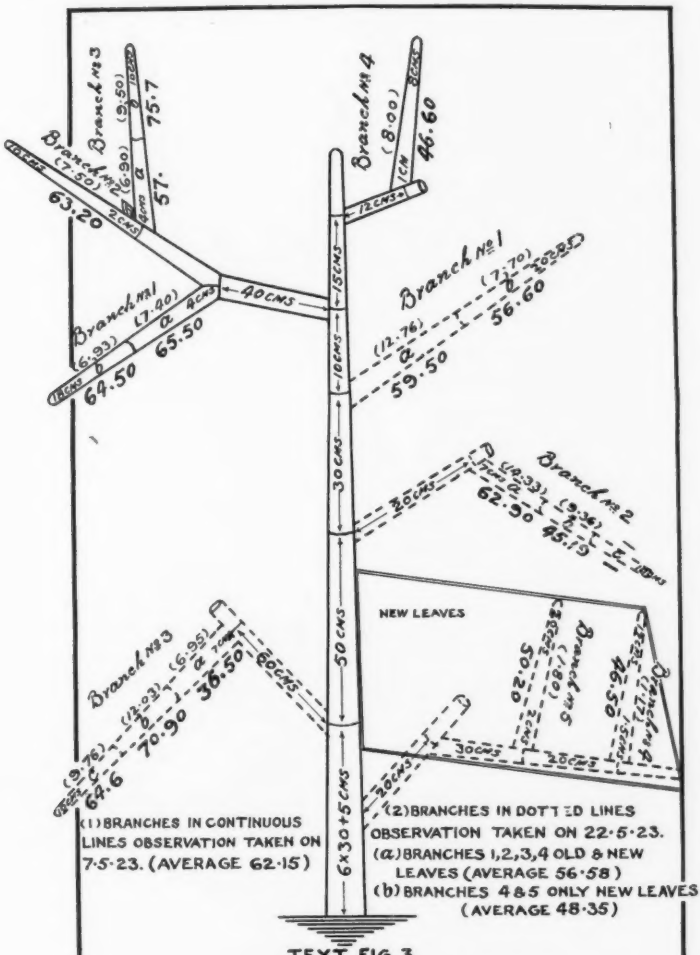
TABLE VIII

BAUHINIA VARIEGATA TREE NO. 4

DATE	BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC CONDUCTIVITY OR SPECIFIC VOLUME
May 10, 1923	1*a*	12.50	0.2260	55.30
	1*b*	10.90	0.1782	61.10
	2*a*	3.23	0.0973	33.40
	3*a*	13.23	0.2479	53.30
	3*b*	12.10	0.2050	59.00
	4*a*	6.30	0.1260	50.00
	4*b*	3.76	0.0772	48.70
	5*a*	8.00	0.1530	52.10
	5*b*	6.86	0.1186	59.00
	6*a*	4.76	0.0997	47.70
	6*b*	2.31	0.0593	40.00
	7*a*	3.51	0.0837	42.00
		Average of readings 50.13		
October 28, 1923	1*a*	6.50	0.1402	46.30
	1*b*	4.55	0.1019	44.65
	1*c*	1.65	0.0526	31.30
	2*a*	9.90	0.2115	46.80
	2*b*	7.40	0.1370	54.01
	2*c*	3.275	0.0637	51.40
	2*d*	0.7625	0.04349	17.50
	3*a*	7.35	0.1757	41.97
	3*b*	4.075	0.1130	36.60
	4*a*	5.275	0.1363	38.70
	4*b*	4.30	0.0997	43.10
	4*c*	0.675	0.07307	9.20
	5*a*	8.00	0.1664	42.67
	5*b*	2.90	0.1213	23.90
	5*c*	0.4275	0.0562	7.60
		Average of readings 35.71		

May 22 included branches, some of which contained a still larger proportion of young leaves, and others only the young leaves. The detailed results are given in fig. 3, where the letterings have the same significance as in the previous figures. On comparing the averages from these three lots (62.1, 56.58, and 48.35 respectively), it will be seen that the gradation of specific conductivity with reference to

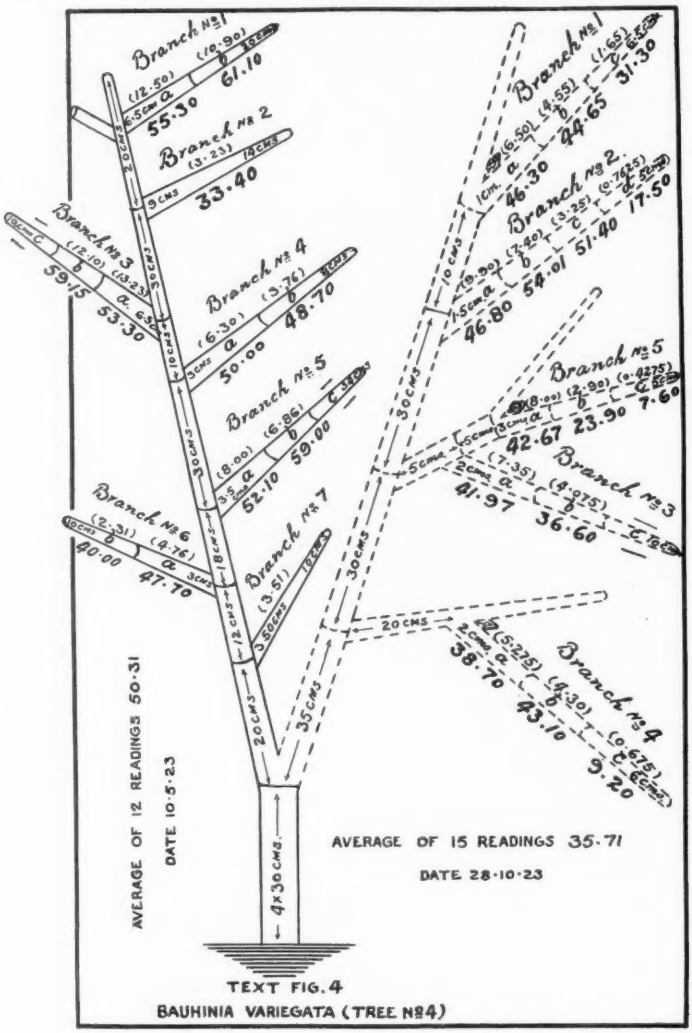
age is similar to that noticed in the first set of observations, indicating again a sudden fall immediately after the new leaves are produced.



TEXT FIG. 3
BAUHINIA VARIEGATA (TREE No 2)

OBSERVATIONS AT DIFFERENT PERIODS OF THE YEAR

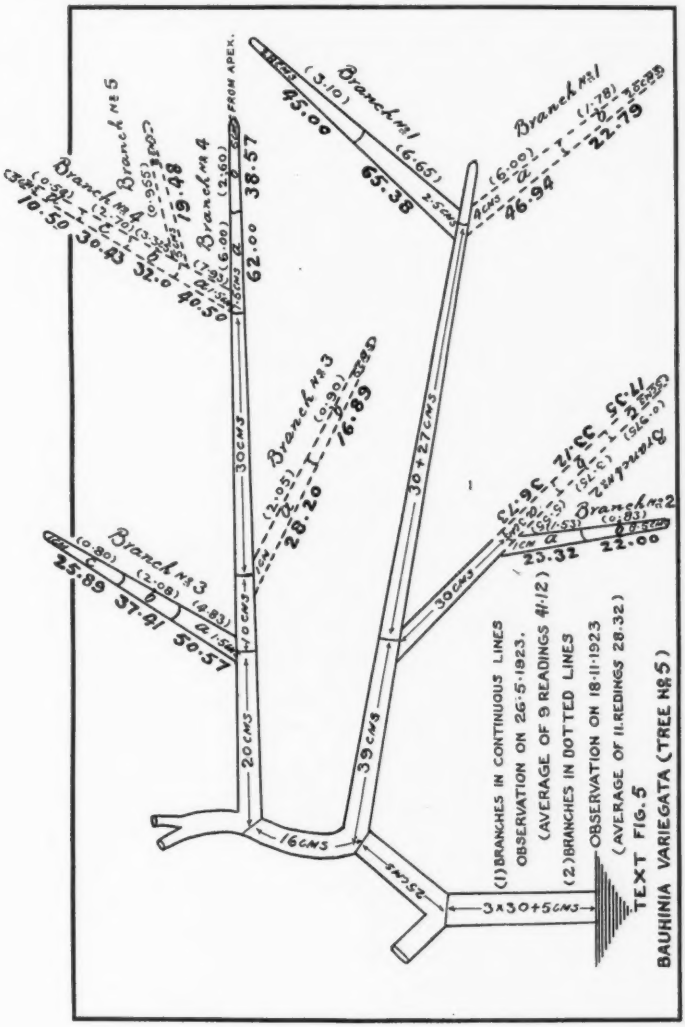
For this series of observations, comparisons were again made between the averages of individual trees and of different branches of the



TEXT FIG. 4

BAUHINIA VARIEGATA (TREE №4)

same tree at different periods of the year, that is, once during the period of leaf fall and again when the new leaves were fully developed. In the first set of observations, the averages of results of trees



nos. 1 and 2 which were obtained in May 1923 (tables VI and VII) are compared with those of tree no. 4 (table VIII*b*) which were obtained on October 28 when the new leaves were fully developed. The averages of trees nos. 1 and 2 are 61.02 and 57.58 respectively, but that of tree no. 4 is much lower, 35.71, thus confirming again the general conclusion already drawn. It is also worth noticing here

TABLE IX

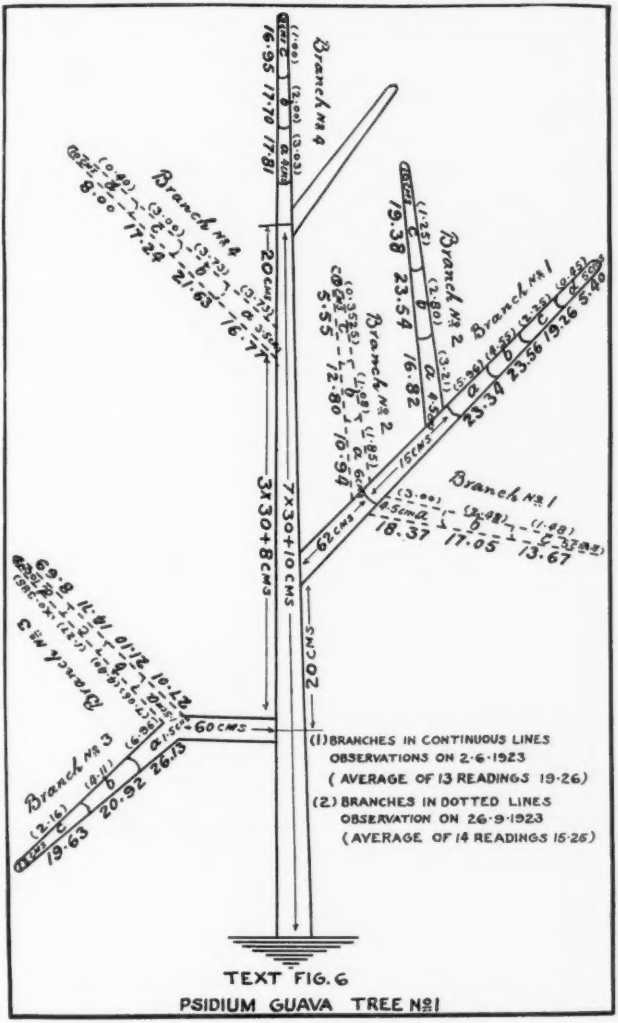
BAUHINIA VARIEGATA TREE NO. 5

DATE	BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
May 26, 1923	1*a*	6.65	0.1017	65.38
	1*b*	3.10	0.0689	45.00
	2*a*	1.53	0.0656	23.32
	2*b*	0.85	0.0388	22.00
	3*a*	4.83	0.0955	50.57
	3*b*	2.08	0.0566	37.41
	3*c*	0.80	0.0309	25.89
	4*a*	6.00	0.0968	62.00
	4*b*	2.60	0.0674	38.57
		Average of readings		41.12
November 18, 1923	1*a*	6.00	0.1278	46.94
	1*b*	1.78	0.0790	22.79
	2*a*	5.55	0.1511	36.73
	2*b*	3.75	0.1132	33.12
	2*c*	0.975	0.0562	17.35
	3*a*	2.05	0.0727	28.20
	3*b*	0.90	0.0533	16.89
	4*a*	7.93	0.1745	45.50
	4*b*	3.325	0.1041	32.00
	4*c*	2.70	0.0887	30.43
	4*d*	0.50	0.0476	10.50
	5*a*	0.955	0.0485	19.48
		Average of readings		28.32

that the transpiring capacity of the atmosphere is much lower in October than in the summer months of April, May, and June, a point which will be referred to later.

The most convincing proof of the general phenomenon comes from the second set of observations, where specific conductivities of different branches of the same tree are compared in different seasons of the year. For this set of observations *Psidium guava* was included along with *Bauhinia variegata*. In *B. variegata* two trees (nos. 4 and

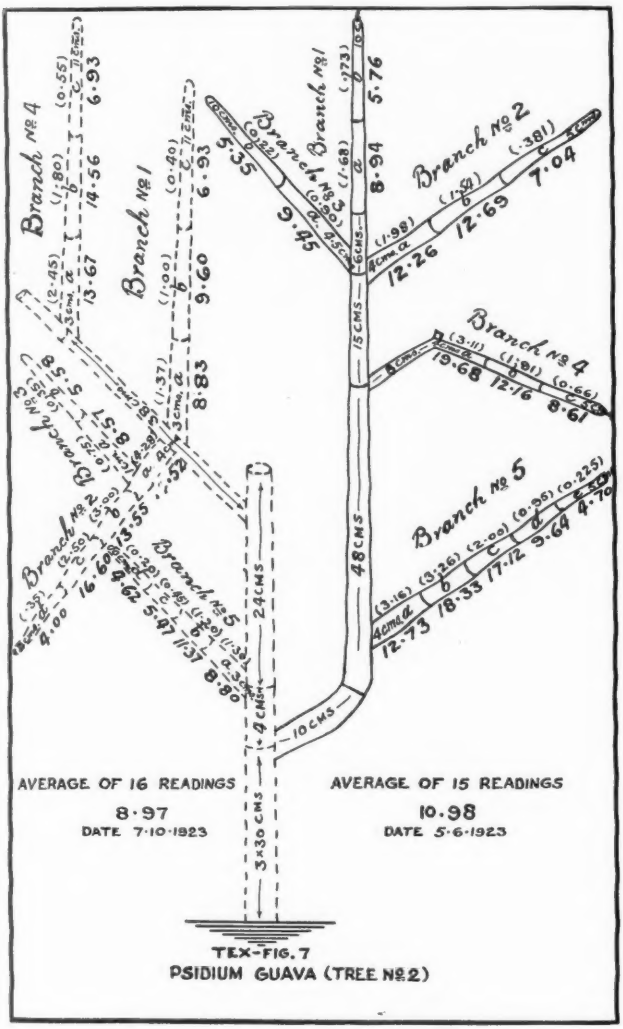
5) were used. In each of these the first set of observations was made on a number of branches in May 1923, when the plants were just producing new leaves, and the second set in October and November,



TEXT FIG. 6

PSIDIUM GUAVA TREE No 1

when the new leaves were fully mature. The results are given in diagrammatic form in figs. 4 and 5, and are also tabulated in tables VIII and IX respectively. Similar observations were made on two



TEX-FIG. 7

PSIDIUM GUAVA (TREE № 2)

trees of *Psidium guava*, the first set of observations in each tree falling in the month of June when the trees were entirely leafless, and the second set in September and October when the new leaves

TABLE X

PSIDIUM GUAVA TREE NO. 2

DATE	BRANCH NO. AND PORTION OF BRANCH	MEAN ABSOLUTE VOLUME (CC.)	ACTUAL AREA OF WOOD (SQ. CM.)	SPECIFIC VOLUME OR SPECIFIC CONDUCTIVITY
June 5, 1923	1*a*	1.68	0.1878	8.94
	1*b*	0.73	0.1266	5.76
	2*a*	1.98	0.1615	12.26
	2*b*	1.54	0.1213	12.69
	2*c*	0.381	0.0541	7.04
	3*a*	0.90	0.0952	9.45
	3*b*	0.23	0.0411	5.67
	4*a*	3.11	0.1580	19.68
	4*b*	1.91	0.1559	12.16
	4*c*	0.66	0.0766	8.61
	5*a*	3.16	0.2484	12.73
	5*b*	3.26	0.1778	18.33
	5*c*	2.00	0.1168	17.12
	5*d*	0.95	0.0985	9.64
	5*e*	0.225	0.0479	4.70
			Average of readings	10.98
October 7, 1923	1*a*	1.375	0.1550	8.83
	1*b*	1.00	0.1041	9.60
	1*c*	0.40	0.0576	6.93
	2*a*	4.28	0.2948	14.52
	2*b*	3.00	0.2213	13.55
	2*c*	2.50	0.1500	16.60
	2*d*	0.35	0.0920	4.00
	3*a*	0.75	0.0875	8.57
	3*b*	0.35	0.0621	5.58
	4*a*	2.45	0.1792	13.67
	4*b*	1.80	0.1236	14.56
	4*c*	0.55	0.0793	6.93
	5*a*	1.30	0.1479	8.80
	5*b*	1.20	0.1055	11.37
	5*c*	0.45	0.0822	5.47
	5*d*	0.20	0.0433	4.62
			Average of readings	8.97

had developed well. The results of *Psidium guava* are represented in figs. 6 and 7 and in tables V and X respectively, which do not require any further explanation. The results are mutually confirmatory. The averages during the earlier part of the year are always higher than those during the latter part. Thus for instance, in *Bauhi-*

nia variegata, tree no. 5 (cf. fig. 5 and table IX), the average of nine readings during the period the new leaves were just being produced is 41.12, while it is 28.32 for twelve readings at the time when new leaves were fully mature.

Discussion and conclusions

The mutually confirmatory results from different sets of comparisons leave no reason for doubting that the capacity of the conducting elements for conducting water is highest just before or during the time of leaf fall, and decreases when the new leaves have come. From the data in hand, a continuous graph of seasonal variations in specific conductivity throughout the year cannot be drawn unless more observations during different periods of the year are taken. The general conclusion can be drawn, however, that variations in the specific conductivity appear to be correlated with the varying demands on the water supply made by the transpiring leaves. The conditions for transpiration are very severe during the summer months of April, May, and June, when the shedding of leaves generally occurs in Benares. The rainy season sets in during the last week of June and continues until the middle of October. The cold period commences immediately afterwards, that is, the first week of November, and continues up to about the middle of February or the beginning of March, when spring sets in, to be followed later by the intense dry heat of the summer months. The increased humidity during the rainy season and the low temperature during the cold season retard transpiration, and specific conductivity is comparatively low during these periods. It begins to rise during the summer months with the increase in the rate of transpiration. That the specific conductivity is correlated with the varying demands made by the leaves on the water supply is also confirmed by FARMER'S and our observations on the deciduous and evergreen trees. This correlation is well seen in a further set of observations on the relation between the specific conductivity and the structure of the wood embodied in a separate paper (10). An inspection of the table included there indicates that, in general, the specific conductivity decreases with the "xerophytic character" of the leaves. The greatest value is found in a creeper, *Ipomea pentaphylla*. FARMER has also noticed an increase in the conductivity of the climbing species as compared with the

creeping or shrubby forms. In the case of the climbers, the transpiratory stream has to traverse a long distance, and the cross-sectional area available for transportation being comparatively small, the large demand on the top is met by increasing the specific conductivity (6).

That there should be a correlation between the demands made by the leaves on the water supply and the specific conductivity is evident from HOLMES' (7) and RIVETT'S (13) observations on the constitution of wood from the standpoint of its efficiency for conducting water. Variations in the specific conductivity are determined by the proportion of efficient water conducting elements to the total quantity of wood, their cross-sectional area, and their length, the last influencing the number of walls the water has to traverse. A reference to the table in the publication referred to (10) also indicates that the average area of the vessels varies in general with the specific conductivity, with few exceptions. In other words, variation in the specific conductivity is merely an expression of variation in the anatomical construction of the wood according to the demands made by the plants on water supply. HABERLANDT gives a great number of illustrations showing the correlation between the anatomical construction of the wood and the physiological requirements of the plants with reference to water. JOST also has shown that the extent of the transpiring surface influences the differentiation of the vascular system in a remarkable manner. Likewise KOHL'S and SCHENCK'S experiments on a number of plants grown in damp and dry atmosphere indicate that the development of the vascular system is necessarily correlated with the physiological necessities of the plants for water supply.[1]

The fact that variations in the specific conductivity are correlated with the needs of transpiration is also remarkable in another way. The phenomenon appears to be another expression of the general principle of LE CHETALIER'S theorem mentioned by Mrs. SHREVE (15) in her recent paper on the seasonal variation of transpiring power in *Encelia farinosa*. According to LE CHETALIER'S theorem, if a system is subjected to stress it tends to move in such a direction as to counteract the effects of the stress. An increased demand on the water supply is met by the plant by a simultaneous

[1] JOST, KOHL, and SCHENCK, quoted from HABERLANDT 6.

increase in the capacity of the wood to conduct water, inducing an absolute increase in the supply that may reasonably be postulated, provided the supply of water to the conducting elements is not limiting the rate of flow. This general principle appears to be capable of a wider application with reference to the internal working of the living organism than merely to water supply. The problem is discussed by the first writer in a recent publication under the heading "Auto-regulation of physiological processes" (9), to which only a passing reference is necessary here.

The explanation of the depression in the specific conductivity when new leaves are produced probably lies in the fact that new growth takes place in the wood. This new growth consists of many living elements and comparatively undeveloped tracheids and vessels, reducing thus the efficiency of the conducting channels.

From the foregoing description it is clear that there is, during the time of leaf fall, an increased supply of water to the leaves which can safely be postulated by the increased capacity of the wood for conducting water, provided the water supply to the conducting elements is not limiting the rate of flow. If water supply has anything to do with the phenomenon of leaf fall, therefore, the water lost by the leaves by transpiration during the period must be still greater, inducing an unfavorable balance between supply and demand. This point can be determined only when the relations between the supply of water and the demands made by the transpiring leaves are thoroughly investigated during different seasons of the year. In measuring transpiration, one has to take into consideration not merely the effect of external environment on the process, but also variations in the internal transpiring power of the plant, which Mrs. SHREVE has clearly demonstrated (15). Work on these lines is in progress; meanwhile it is sufficient to record here the correlation existing between the period of leaf fall and the increase in the conducting capacity of the wood.

Summary

1. There is a fundamental distinction between monopodial and sympodial growth, the conductivity in the latter falling off rapidly from the base to the apex.

2. The distinction drawn by FARMER between deciduous and evergreen trees refers primarily to the respective demands made by them on the water supply for purposes of transpiration.

3. There is a correlation between the period of leaf fall and the increased capacity of the wood for conducting water.

BENARES HINDU UNIVERSITY
INDIA

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STRUCTURE OF SPORE WALL IN GANODERMA

LESLIE C. COLEMAN

(WITH PLATE V)

In the classification of the Polyporaceae, spore characters have usually received but little attention. This is due largely to the fact that in many forms spores have not as yet been observed. An incorrect interpretation of spore structure in certain forms which have been variously placed in the genera *Fomes*, *Ganoderma*, and *Elfvingia*, however, has partially been responsible for the failure to use what is undoubtedly a valuable diagnostic character. The present investigation has been undertaken in an attempt to clear up the misconceptions which have arisen in this regard.

The genus *Ganoderma* was established by KARSTEN (**7**) as including only one species, *G. lucidum*, characterized by having the pileus covered by a shiny crust, and the spores ovate or elliptical, warty, and yellowish brown in color. Subsequent systematic writers, like PATOUILLARD (**10**) and MURRILL (**9**), have retained the genus *Ganoderma* but on the basis of the shiny crust alone. Others, like SACCARDO (**11**), have given it only subgeneric rank. The warty character of the spore coat has been considered by them all as of subordinate importance. PATOUILLARD, it is true, has used this character in subdividing his genus *Ganoderma*, but the other writers have noted it only in specific descriptions. In fact, MURRILL places many of the forms which show quite definite affinities with *G. lucidum* as to spore characters in KARSTEN'S genus *Elfvingia*, which indicates the small importance he attaches to such characters.

All of the writers just cited, as well as others, as a matter of fact have misinterpreted the character of the spore wall. This was first pointed out by ATKINSON (**2, 3**) in two papers which appeared in 1908. He showed that the outer surface of the spore wall in a number of forms examined by him is smooth, not echinulate or verrucose as had been stated previously. In the first of the two papers he states:

> The spore wall is hyaline or nearly so and is perforated by numerous slender rod-like extensions of a brown or yellowish brown substance which appear as

if they were projections of the colored contents of the spore. These do not extend beyond the outer surface of the wall, and they radiate from the endospore through the hyaline wall. They are especially prominent at the smaller end of the oval spore where the hyaline wall is considerably thicker, sometimes forming a broad cone-like cap to the spore.

In his second paper, dealing with *Ganoderma applanatum* Pers., he states:

Not only is the spore wall hyaline or nearly so, it appears to be of a less firm consistency than the dark rods or perforating substance. In some cases, perhaps due to a certain age of the spore wall, when its consistency is less firm than at other times, the spore wall collapses to a certain extent and there is a tendency for the hyaline part of the wall to collapse between these dark areas, thus giving a roughened or slightly echinulate appearance to the spore.

In another part of the same paper he states, "The hyaline or nearly hyaline wall is perforated with numerous short dark lines or plugs which radiate from the spore content or endospore membrane through the epispore and end even with its external surface."

It will be seen that ATKINSON was in doubt as to the real nature of the "dark rods" to which he ascribed the echinulate appearance in surface views of the spore. It is interesting in this connection to note that PATOUILLARD in 1899 had observed that the spore wall in the forms studied by him was differentiated into distinct epispore and endospore. He states:

Elles sont formées d'une membrane interne épaisse et colorée en brune ou jaune plus ou moins foncé. Sur cette membrane on observe souvent des petites verrues serrées; l'épispore est mince, incolore et se moule exactement sur les asperités de l'endospore, c'est elle qui est échancrée et forme une pointe incolore à la base de la spore.

Miss AMES (1), working in ATKINSON'S laboratory, has confirmed ATKINSON'S description of the spore wall structure. She lists sixteen species of *Ganoderma* examined, and states that they are all characterized by having spore walls smooth, with dark lines extending into the hyaline or nearly hyaline wall from the darker spore content.

WHITE (15) gives a decidedly different interpretation to the structure of the spore wall in *Fomes applanatus*. He states:

In studying its development we find that the basidiospore starts out with a hyaline wall and then that later within this outer thin walled basidiospore a

rough-coated thick and yellow walled endospore is formed. The spore "wall" in one sense then is accordingly double. As the endospore is more shortly elliptical than the original basidiospore, the tip of the latter is not occupied, and this hyaline tip being thin walled and without supporting contents usually collapses. This gives to the mature spore the "truncated" appearance so invariably noted.

Finally, BULLER (4) disagrees with WHITE'S interpretation, and in general confirms ATKINSON'S observations. He states:

> It seems to me that each spore has a continuous rather thick wall made up of two layers: (1) an outer very thin, colorless, homogeneous layer formed whilst the spore is growing from a tiny rudiment to full size, and (2) an inner and a much thicker layer formed more slowly during the ripening of the spore, of a whitish or yellowish color and marked from within outwards by numerous fine yellowish brown striae. What the nature of these striae is I do not know, but I do not regard them as papillae.

From these citations it will be seen that the structure of the spore wall in these interesting forms is still a matter of uncertainty. This is hardly to be wondered at when we consider that apparently all the observations so far have been made on intact spores, either in collected spore material or in hand sections of the sporophore unstained in any way. When we remember that the spore wall is scarcely 0.5 μ thick, the difficulty of making definite observations will be understood. When, therefore, Dr. FAULL suggested to me the advisability of making a more thorough study of the subject, I gladly availed myself of the opportunity so generously furnished by him. He placed at my disposal excellent material of a number of forms. To this has been added a huge mass of spore material of *Ganoderma* (*Fomes*) *applanatum* kindly given me by Dr. J. H. WHITE.

Material and methods

The basis of this study has been material of *Ganoderma applanatum* and *G. tsugae;* of the former I have had abundant spore material as well as sporophore material fixed in picro-sublimate; of the latter I have had good wet material in alcohol. In addition to this I have studied wet material of *G. tornatum* and *G. Lionellii,* spore material and dry sporophore material of *G. lobatum.* For comparison, material of a distinctly different form, *Fomes fomentarius,* was given to me by Dr. FAULL both as imbedded and spore material, and has been included in the study. Miss AMES included this form in the

genus *Ganoderma* on the ground of spore characters. As a matter of fact the spores are of a very different type, so much so that it seems impossible that she could have observed them at all. Previous microscopic studies of *Ganoderma lucidum* had verified the conclusions of ATKINSON (**2**) so far as the similarity of the spore wall in this form to that in the other forms mentioned is concerned.

As the spore coat is hard, the material for critical study was imbedded in paraffin of 60° melting point, and for most of the sectioning resort was had to the cooling action of an ether spray, a freezing attachment for the microtome not being available. As the spores of *G. applanatum* average about 5 μ in thickness, those of *G. tsugae* being somewhat larger, sections were cut down to 2 μ in thickness.

In trials to obtain a differential staining of what seemed to be two parts of the spore wall, the best results were obtained by the use of safranin and Licht Grün. Each of these if used separately was found to stain both parts of the spore wall, the endospore taking up the stain more strongly. A beautiful differential staining, however, was obtained when the sections were kept in the safranin bath (1 per cent in 50 per cent alcohol) from 12 to 24 hours, run quickly up through the various grades of alcohol, and kept in the Licht Grün bath (0.5 per cent in 90 per cent alcohol) for from 10 seconds to 1 minute, and then rapidly dehydrated and passed into xylol. This was used as the regular method of staining throughout the investigation.

Mature spores

In thin sections of the sporophore mature spores could be found in abundance, and many of them could be studied in section. *G. tsugae* proved on the whole to be more satisfactory, as its spores are larger than those of *G. applanatum*. The microscopic examination was made with a Zeiss apochromatic 1.5 mm. objective with compensation ocular no. 8. Higher power oculars (Zeiss nos. 12 and 18) were tried, but it was found that they did not give a satisfactory definition.

The microscopic picture, as found in the case of many hundreds of spores examined, showed quite definitely that the interpretation of ATKINSON, Miss AMES, and BULLER is incorrect, while that of

WHITE in the main represents the actual structure of the wall. The hyaline epispore with its conspicuous thickening at the narrower distal end takes on a beautiful green color, the Licht Grün having removed all the safranin in this area. On the other hand, the thicker endospore retains the safranin very strongly where the counter staining had not been too prolonged. The spore content, for the most part, takes on a much lighter stain than the endospore, the nucleus being visible as a more deeply stained mass in many of the sections. From the endospore project fine processes or spines, which are somewhat thicker at the inner end out into the epispore. These projections appear in some cases not to extend quite to the outer surface of the epispore, although I am not prepared to speak definitely on this point. These projections or spines show a red stain uniform with that of the endospore, and appear quite definitely as outgrowths from it. They are not rodlike extensions of the spore contents, as ATKINSON and Miss AMES believed, nor are they striae extending through the endospore wall as indicated by BULLER. These projections are frequently to be found, especially in *G. tsugae*, beautifully defined in the hyaline cap or beak. Here they show as definite red lines against the greenly stained groundwork of the beak.

A further consideration of this hyaline cap or beak is necessary. WHITE pictures it as empty. He uses the term "not occupied," and accounts for its collapse, which is so frequently to be seen in mature spores, on this supposition. The whole beak, however, even in the thinnest sections, is stained uniformly green, which would not be the case of course were there a space between the endospore and the epispore in this region.

Figs. 1 and 3 show the structure of the spore wall in *G. tsugae* and *G. applanatum* respectively, the endospore being marked in black and the spore contents being omitted. In addition to the points just mentioned, fig. 1 brings out another interesting feature of the spore wall, which ATKINSON has already noted, but which the microphotographs accompanying his papers do not illustrate; that is, the fact that at the proximal end of the spore there is a small pore in the endospore which is somewhat asymmetrically placed. Around this pore the endospore projects outward, almost if not

quite to the outer surface of the epispore. This, as ATKINSON stated, marks the point of attachment of the spore to the sterigma. The view expressed in most systematic works on these forms, that the spore is attached to the sterigma by its hyaline or (as is frequently stated) truncate narrower end, has been disproved by ATKINSON, WHITE, and BULLER.

Figs. 2, 4, and 5 give similar sectional views of the spores of *G. lobatum*, *G. tornatum*, and *G. Lionettii* respectively. The structure of the spore wall in these forms is seen to be similar in all essential respects to that found in *G. tsugae* and *G. applanatum*. In the case of the last two forms, however, there were no projections of the endospore out into the hyaline beak, although the beak itself takes the Licht Grün stain even more strongly than in the other forms.

It may perhaps be wondered how such able observers as ATKINSON and BULLER could have misinterpreted the structure of the spore wall. It is quite explicable when we consider that the endospore, although yellowish brown in color, is quite transparent. Thus when the microscope is focused in the median plane of the spore, the projections above and beneath appear in the picture even under the highest magnifications and give the optical effect of striations. Certainty as to the structure can be attained only after a study of many very thin spore sections, something which I believe neither ATKINSON nor BULLER made.

Reference has already been made to the observations of ATKINSON on the collapse or shrinkage of the hyaline epispore, while, as WHITE has noted, the collapse of the hyaline beak in *G. applanatum* is a phenomenon very generally observed. As a matter of fact, in all dry material most mature spores show this collapse so markedly that in systematic works the spores of these forms are generally described as "truncate at the base." In the case of two of the forms studied, *G. tornatum* and *G. Lionettii*, where the long hyaline beak is not supported by any projections of the endospore, the beak apparently does not collapse, but instead breaks off. As to the collapse at other regions of the spore wall, I have not seen any evidence of the epispore becoming molded on to the echinulate surface of the endospore, as described by PATOUILLARD and indicated by ATKINSON. Commonly, however, the epispore seems to have shrunk so as

to have its outer surface resting on the ends of the spines of the endospore. The variation in thickness of the epispore is no doubt due to the presence of varying quantities of water. This question will be discussed later in dealing with the chemical nature of the spore wall.

Development

BULLER has already indicated the general course of development of the spore wall. He states that the endospore begins to make its appearance only during the ripening of the spore, that is, after the spore has attained its full size. A careful study of developmental stages in *G. applanatum* has shown that, while there is no sign of endospore formation until after the spore has taken on its definitive shape, measurements indicate that the spore continues to increase in size after this process has begun. Figs. 7–13 show stages in spore development with special reference to the differentiation of the spore wall. In the stage illustrated in fig. 7, the young half-grown spores were found stained almost entirely green after the safranin Licht Grün treatment. A few coarse granules were to be found scattered irregularly in the cytoplasm, which had retained the safranin stain, but these bore no demonstrable relationship to the cell wall. In this stage the nuclei had not yet migrated from the basidium.

Fig. 8, showing in section two basidiospores, illustrates what must be considered as the earliest demonstrable stage of endospore formation. Here we have the epispore and cytoplasm stained green. In addition there is a line of rather coarse granules which have retained the red stain, and which appear just inside the spore surface. At the apex of the spore, they have been laid down at a distance from the point. Between them and the surface is a distinct area free from granules which represents the epispore of the mature spore. A similar stage is illustrated in figs. 9 and 11, where a spore is shown in longitudinal and transverse section respectively.

In figs. 10 and 12 a later stage is shown. The granules have fused into a continuous membrane, from which short projections have grown out toward the epispore surface. It seems highly probable that up to this stage, and in fact even later, the limiting membrane of the spore has not yet assumed the character of a definite wall, although there has been a differentiation of a hyaline layer. The outgrowth of spiny projections from the endospore, which finally

reach almost or quite to the outer surface of the spore, would be difficult to understand if a definite epispore had already been formed. On the other hand, the presence of a plastic episporic area bounded by an outer limiting membrane would allow for this outgrowth without any difficulty. WHITE'S conception of an endospore quite separate from the epispore is incorrect, I think. It is true that spores and fragments of spores can frequently be found which show portions of the epispore separated from the endospore, but this is probably a tearing along the line of demarcation between differently organized layers of a single wall, rather than a separation of two distinct walls.

Chemical composition

To verify more fully the conclusions reached as a result of microscopic examination, and to ascertain if possible the chemical nature of the episporic and endosporic layers, I subjected the wall to microchemical tests. The work of GILSON (5), WINTERSTEIN (16), and VAN WISSELINGH (13) has shown that the cell wall in most fungi does not contain cellulose. VAN WISSELINGH has further shown that its place is taken for the most part by chitin. Repeated and prolonged tests made on the spores and sections of sporophores of *G. applanatum*, *G. tsugae*, and *G. tornatum* with chlorzinciodine, iodine in potassium iodide with dilute H_2SO_4, and cuprammonium oxide gave no evidence of cellulose, either in the spore wall or in the mycelium of the sporophore. Both chlorzinciodine and cuprammonium oxide produced a distinct swelling of the epispore, but it did not lead to its separation from the endospore layer. HANSEN (6), in his study of the spores of *Coprinus stercorarius*, has recorded a similar swelling of the epispore in that form, when the spores were treated with chlorzinciodine, which in the case of that form led to the separation of the two layers.

Tests for chitin were carried out according to VAN WISSELINGH'S method and VOUK'S (14) modification. Of the two, VAN WISSELINGH'S original method was found much more satisfactory. It consists in heating the material to be examined in concentrated KOH in a sealed tube to a temperature of 160°–180° C., which changes the chitin to chitosan, washing with 90 per cent alcohol, and then testing on the slide with dilute iodine in potassium iodide to which a drop of dilute H_2SO_4 is added. The chitosan gives a very character-

istic reddish violet color reaction when treated in this way. Dry spore material of *G. applanatum*, celloidin sections of the same species, and hand sections of *G. tsugae* were used for the purpose. After heating, the KOH solution was diluted with distilled water to enable centrifuging, the material separated in a centrifuge, and washed with 90 per cent alcohol. The spores and shreds of sections remaining after this treatment were then treated on the slide. It was found in the case of spore material that, in the final centrifuging with alcohol, the whole mass distributed itself on the sides of the tube and stuck there as if it were gummed, and could not be dislodged by the centrifuging process.

An examination of the spore material after treatment with the coloring reagent showed both epispore and endospore intact. The cell contents had entirely disappeared, of course. The epispore remained quite hyaline, while the endospore had taken a beautiful reddish violet color. Figs. 13 and 14 show two spores thus treated in optical section, the blackened portion of the wall representing the reddish violet endospore. As will be noted in comparing these figures with fig. 3, there has been a slight swelling of both epispore and endospore, with a shortening of the spiny processes on the latter, so as to separate them distinctly from the surface of the spore. The results obtained in this test show that ATKINSON's conception of the spore wall is erroneous, and that the striae observed by BULLER are an optical illusion.

It appears certain that the endospore does not consist entirely of chitin. According to VAN WISSELINGH, chitosan dissolves in dilute HCl, and an attempt to dissolve out the endospore after treatment with KOH failed even when the slide was heated. We must conclude, therefore, that the endospore consists of chitin and some other compound or compounds at present unknown.

The study of the epispore was more difficult and puzzling. I was inclined to believe that this portion of the wall contains a gum or slime. The presence of such a substance seemed probable from the fact that spores caught on sporetraps made of microscopic slides adhere very firmly, and can be washed off only with difficulty. The epispore, however, could not consist entirely or even mainly of a gum, as it does not swell up very appreciably when the spores are

kept in water even for long periods. I have not been able to obtain fresh spores for examination, however, and they might conceivably give somewhat different results from spores which have been kept for several years on a glass slide.

I attempted to obtain a differential stain of the epispore with Ruthenium red, which according to MANGIN (8) is an extremely valuable differentiating stain for pectin bodies and the gums and slimes derived from them. While a stain of any kind is admittedly a very unsafe means of distinguishing groups of chemical compounds, it was thought that the use of this one might throw light on the question of the composition of the epispore. Spores of *G. applanatum* stained with Ruthenium red (1 part in 5000) undoubtedly give a color in the episporic region, but the endospore and also the spore contents take up the stain. It is obvious therefore that this is not a specific stain for these bodies; in fact, TOBLER (12) has already shown that other bodies, such as glycogen, take up the stain strongly.

Results from treating sections of the sporophore of *G. tornatum* were even less satisfactory. The very pronounced hyaline beak of the spore remained unstained, while the endospore and spore content became colored. The hymenial layer also appeared red, while the brown trama remained unstained. The presence of glycogen would account for the staining of the hymenial layer and the spore contents, but not for that of the endospore.

Finally I attempted to dissolve the epispore, leaving the endospore intact. For the purpose, following VAN WISSELINGH, spore material of *G. applanatum* was heated in glycerin to 290° C. (the boiling point of glycerin). In this way evidence was obtained of the solution of the epispore, but portions of it usually remained. Heating in dilute H_2SO_4 gave much better results. Spore material of both *G. applanatum* and *G. tornatum* heated on the slide in from 5 to 20 per cent H_2SO_4 gave large numbers in which the epispore had entirely disappeared, leaving the endospore intact. This reaction indicates that the epispore has the characteristics of a hemicellulose, although it gives no color reaction with chlorzinciodine or with iodine and dilute H_2SO_4. In any case its chemical composition is obviously very distinct from that of the endosporic layer of the spore wall.

Conclusions

My conception of the spore wall structure in these forms is as follows. The epispore represents the primitive spore wall, and is probably comparable with the undifferentiated spore wall of such a form as *Fomes fomentarius*, which is very thin, and which, treated by the same methods used for *Ganoderma* spores, has shown no differentiation whatever. It consists of a hemicellulose with possibly a gum, which latter, if present, functions in attaching the spore to the surface upon which it falls. The endospore is composed of chitin and other compound or compounds. It is laid down on the inner margin of the epispore as a series of granules which later fuse to form a membrane. This thickens and develops on its outer surface spiny processes which project into the epispore at a time when the latter is still plastic. The whole endospore structure obviously functions as a sort of skeletal support to the thin and collapsible primary spore wall.

It seems probable that this highly specialized structure has to do with preserving the spore through unfavorable seasons. It is a fact that the spores of both *G. applanatum* and *G. lucidum* are extremely difficult to germinate under laboratory conditions. WHITE, in his work on the former species, was rarely able to obtain germination, and could not establish the factors which governed it. My work on *G. lucidum* was even less successful, for, although attempted repeatedly, I have never succeeded in obtaining a single germination. If we take a thin walled spore such as that of *Fomes fomentarius*, germination of fresh material is readily to be obtained according to FAULL, who has made a thorough study of the subject.

Possibly the fact that *G. applanatum*, and presumably other species of *Ganoderma*, discharge spores over long periods during which conditions for germination cannot always be favorable, while *Fomes fomentarius* discharges only during a comparatively short period in the spring, may bear some relation to the differing structure of the spore wall.

The peculiar structure of the spore wall described in this paper is characteristic of species found in such widely separated areas as America, Europe, and India. It would seem to be a character of much greater importance from a systematic standpoint than many

of those at present being used in the classification of the Polyporaceae. A revision of the genera *Fomes*, *Ganoderma*, and *Elfvingia*, which in standard systematic works are given as containing species with the spore characters here described, together with other forms showing quite different spore characters, seems to be urgently required if our classification is to represent real relationships.

As indicated by the title of this paper, I consider that all forms showing the spore characters described should be brought together under the genus *Ganoderma* Karst.

UNIVERSITY OF TORONTO
TORONTO, CANADA

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EXPLANATION OF PLATE V

All figures have been drawn with the aid of an Abbé camera lucida, using Zeiss apochrematic 1.5 mm. objective, N. ap. 1.30 mm. and compensating ocular no. 8. They represent a magnification of approximately 2000 diameters.

FIG. 1.—Basidiospore of *Ganoderma tsugae* in longitudinal section.

FIG. 2.—Basidiospore of *G. lobatum* in longitudinal section.

FIG. 3.—Basidiospore of *G. applanatum* in longitudinal section.

FIG. 4.—Basidiospore of *G. tornatum* in longitudinal section.

FIG. 5.—Basidiospore of *G. Lionettii* in longitudinal section.

FIG. 6.—Basidium of *G. applanatum* showing first signs of basidiospore formation on sterigma to left; section fixed in picrosublimate and stained with safranin and Licht Grün (same process used for figs. 7–12).

FIG. 7.—Longitudinal section of basidium of *G. applanatum*, showing three basidiospores about half developed; larger dots represent granules stained red, rest of the spore cytoplasm being stained green.

FIG. 8.—Longitudinal section of basidium of *G. applanatum*, showing basidiospores which have assumed their definitive shape but not their full size; first signs of endospore shown as a line of granules stained red inside the epispore.

FIG. 9.—Longitudinal section of basidiospore of *G. applanatum* which has become detached from the sterigma, showing about same stage as in fig. 8.

FIG. 10.—Longitudinal section of basidiospore of *G. applanatum*, showing endospore granules fused into continuous wall and spiny projections beginning to develop.

FIG. 11.—Transverse section of basidiospore of *G. applanatum*, showing same stage of endospore development as in fig. 9.

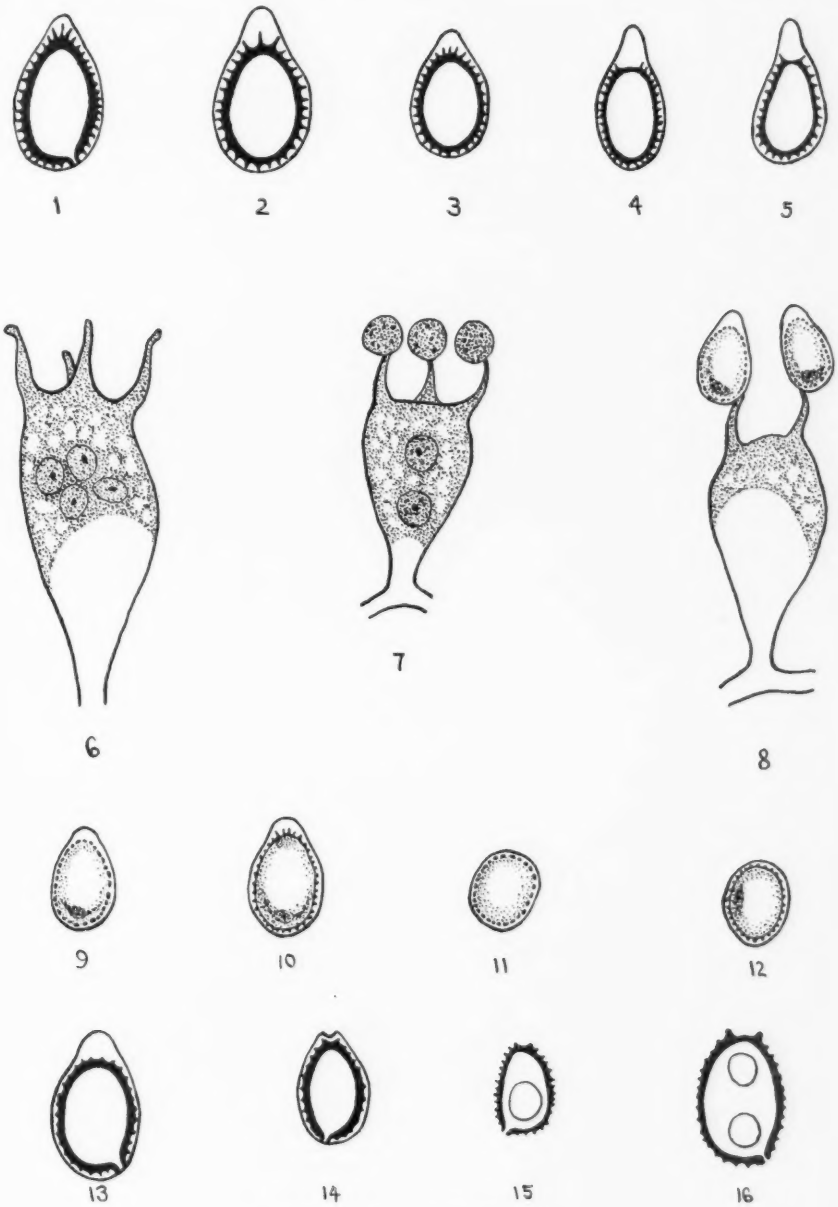
FIG. 12.—Transverse section of basidiospore of *G. applanatum*, showing same stage as in fig. 10.

FIG. 13.—Basidiospore of *G. applanatum* in longitudinal section, showing chitin reaction of the endospore; note swelling of both endospore and epispore, former giving a reddish violet color reaction.

FIG. 14.—Basidiospore of *G. applanatum* in longitudinal section, showing chitin reaction as in fig. 13; in this case hyaline beak has collapsed.

FIG. 15.—Basidiospore of *G. applanatum* in longitudinal section after having been heated in 20 per cent H_2SO_4 which has completely dissolved the epispore.

Fig. 16.—Basidiospore of *G. tornatum* in longitudinal section after being heated in 5 per cent H_2SO_4, giving same result as shown in fig. 15.



COLEMAN on GANODERMA

CORRELATION OF COAL FLORAS IN HENRY COUNTY, MISSOURI, AND THE NARRAGANSETT BASIN[1]

EDA M. ROUND

(WITH THREE FIGURES)

Of all the plant-bearing fossiliferous areas in North America, the region of Henry County, in Missouri, presents the most points of interest to students of the coal flora of Rhode Island. The Missouri series was doubtless a product, geographically, of the same type of marsh conditions which prevailed along the borders of the Great Interior Basin during the Carboniferous, when the Pennsylvania, West Virginia, and Illinois coal was formed; but the comparison of its stratigraphic sequence with that of Rhode Island shows that the two areas were evolved under entirely different conditions, in spite of which many similar plant species developed (table I).

Comparative conditions of deposition

Concerning the Missouri strata, WINSLOW (9) states:

> The sandstones are of white, drab, yellow, and reddish colors . . . . with impressions of leaves and stems. . . . . The limestones are sometimes in massive beds . . . . but always of a fine compact texture. . . . . Beds of coal thin out and disappear; beds of shale pass into sandstone or grade into limestone.

WOODWORTH (7) states of the Rhode Island coal:

> Alternations of fine and medium quartz, quartzite, and granite pebble conglomerates [occur] with pebbly sandstones, sandstone (graywacke), shales, and coal beds, becoming metamorphic southward. Colors: black, blue, green, gray, locally red.

The first point made by WINSLOW calls attention to reddish beds containing plant fossils. This differs from conditions in Rhode Island, where the Wamsutta series leads into the Coal Measures proper and contains actual red beds showing phytiferous impressions. The presence of limestone deposits, however, intercalated be-

[1] Work started in partial fulfillment for the degree of Ph.D. in the Department of Geology, Brown University.

TABLE I

SECTION IN HENRY COUNTY, MISSOURI AND IN NARRAGANSETT BASIN

HENRY COUNTY, MISSOURI				NARRAGANSETT BASIN	
Group	Formation	Stratum	Generalized section	Group	Local areas
	Pleasanton formation	Undifferentiated			Westville shales
					Seekonk sandstone
		Pawnee limestone			Aquidneck shales
	Henrietta formation	Labette shale			Ten-mile River beds
		Fort Scott limestone		Rhode Island Coal Measures	Kingstown series
					Mansfield coal beds
					Cranston coal beds
			Shale, light to black		Sockanosset sandstone
			Coal (Lexington)		Pawtucket shales
			Clay, shale		
			Limestone		
			Shale, sandstone, coal		
Des Moines			Limestone, gray to blue		
			Shale, slaty		
	Cherokee shales		Coal (Mulky)		
		Undifferentiated	Shale, blue		
			Coal (Bevier)		
			Clay, shale, sandstone		
			Limestone		Wamsutta slates and shale, red, gray
			Shale, light to black	Wamsutta	Attleboro sandstones
			Coal (Tebo)		Wamsutta conglomerates
			Shale, sandstone, Mammoth		
			Coal (Jordan)		

tween the carbonaceous shales, is not a feature of the Narragansett Basin (the Wamsutta series excepted), although the rule in Missouri. This difference may be explained by postulating a series of fresh water lakes, marshes, or even playas throughout Rhode Island during the Coal Age; while Missouri, likewise under the influence of fresh waters, was visited at intervals by marine invasions which left behind limestone beds and occasional marine fossils. WHITE (8) refers to the Missouri formations as follows:

> The deposits of the lower portion of the Mesocarboniferous occurred during a period of terrestrial subsidence and advance of the shore line, the result of which is the theoretically complete concealment of earlier beds of the Coal Measures beneath the landward overlaps of succeeding sediments.

The lower members of the Rhode Island Coal Measures show expansion, restriction, or possible extinction of the swampy areas, along presumably fresh water lakes, where the Wamsutta beds overlap the Pondville arkose. The Coal Measures proper, however, although they appear to have developed under varying conditions, yet show, from the evidence of the plant species, a marked tendency to uniformity throughout the area. Table II shows the different fossil plants found to be common to Missouri, in Henry County, and the Narragansett Basin, with the localities from which the specimens were obtained.

Listed specimens

Considering each specimen in the order listed, a few observations concerning local conditions in the Narragansett Basin may be of interest.

CALAMARIALES.—The Calamariales are represented in Rhode Island by many large Calamites, among which are *Calamites cistii* Brgt. and *C. suckowi* Brgt. The leading deposits of these giant forms seem to be in the East Providence section of the state, where they now appear largely in the coarse sandstone layers into which they sank, presumably near their original places of growth, or to which they were carried by water currents of braided or distributary streams. Fruiting cones like *Calamostachys ovalis* Lx. are found from Pawtucket, only a few miles distant from East Providence. Various leaf forms like *Calamocladus longifolius* (Stb.) Brgt. and *C. equisetiformis* (Schl.?) Brgt. are very common, the latter being found in at

TABLE II

Orders	Species	Pawtucket	Valley Falls	Lonsdale	Cranston	Arlington	Sockanosset	Tunnel, Providence	Warwick	Rumford	Boyden Heights	Squantum	Silver Spring	East Providence	Bristol	Warren	Portsmouth	Castle Rock	Newport	Perrins, Mass.	Mansfield, Mass.
Calamariales	1. Calamites cistii Brgt	....	....	....	....	....	....	....	....	....	....	....	+	+	....	....	....	....	....	+	....
	2. Calamites suckowi Brgt	+	+	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....
	3. Calamostachys ovalis Lx	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	4. Calamocladus equisetiformis (Schl.) Brgt	+	+	....	+	....	+	+	+	....	+	....	+	+	+	+	+	+	+	+	+
	5. Calamocladus longifolius (Stb.) Brgt	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....
	6. Annularia ramosa Weiss	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	7. Annularia sphenophylloides (Zenk.) Gutb.	+	+	+	+	+	....	....	....	....	....	+	....	+	+	+	+	....	+	+	+
	8. Annularia stellata (Schl.) Wood	+	+	....	+	....	....	+	....	....	....	....	....	+	+	....	+	....	+	+	+
Sphenophyllales	9. Sphenophyllum cuneifolium (Stb.) Zeil	+	....	+	....	....	....	....	....	+	....	....	+	....	....	....	....	....	....	....	+
	10. Sphenophyllum emarginatum Brgt	....	+	....	....	....	....	....	....	+	....	....	+	....	....	....	+	....	....	....	+
	11. Sphenophyllum fontinalis, nom. nov	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	+	....	....	....	....
	12. Sphenophyllum majus Bronn	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....
Lepidodendrales	13. Lepidophyllum missouriense White	....	+	....	+	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....
	14. Lepidostrobus jenneyi White	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	15. Sigillarioid leaves	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	16. Stigmaria ficoides (Stb.) Brgt	+	+	....	+	....	....	+	....	+	....	....	....	....	....	....	....	....	....	....	....
Filicales and Cycadofilicales	17. Eremopteris missouriensis Lx	+	+	....	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	+
	18. Pseudopecopteris obtusiloba (Brgt.) Lx	+	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	19. Sphenopteris Brittsii Lx	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	20. Sphenopteris capitata White	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....
	21. Sphenopteris chaerophylloides (Brgt.) Presl	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	+	....	....
	22. Sphenopteris cristata (Brgt.) Presl	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	+	....	....
	23. Sphenopteris illinoiensis White	....	+	....	....	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	+
	24. Aloiopteris erosa (Gutb.) White	....	+	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....
	25. Aloiopteris winslovii White	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	26. Pecopteris arborescens (Schl.) Brgt	+	....	....	....	....	....	+	....	....	....	....	....	....	....	....	+	....	+	....	....
	27. Pecopteris candolleana Brgt	+	+	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....
	28. Pecopteris dentata Brgt	+	+	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....
	29. Pecopteris hemitelioides Brgt	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	+	....	....
	30. Pecopteris pseudovestita White	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	31. Alethopteris ambigua Lx	+	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	32. Alethopteris serlii (Brgt.) Goepp	....	....	....	....	....	....	....	....	+	....	....	....	....	....	....	....	....	....	....	+
	33. Alethopteris serlii var. missouriensis White	+	+	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....	....	....	....
	34. Neuropteris rarinervis Bunb	....	+	....	....	....	....	....	....	....	....	....	+	....	....	....	....	....	+	....	+
	35. Neuropteris scheuchzeri Hoff	+	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	36. Aphlebia germari Zeil	....	....	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Cordaitales	37. Cordaites communis Lx	....	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	....

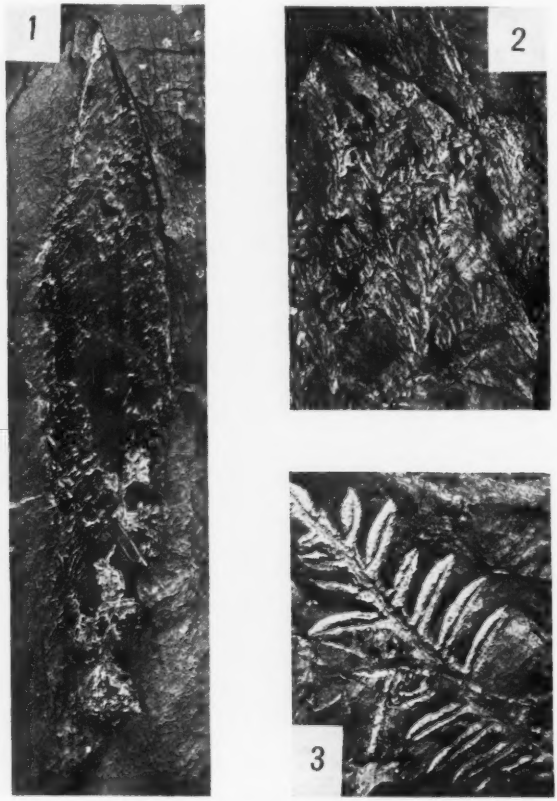
least sixteen of the fossiliferous sections of the Narragansett Basin. Annulariae are sparsely represented by forms resembling *Annularia ramosa* Weiss, whereas *A. sphenophylloides* (Zenk.) Gutb. and *A. stellata* (Schl.) Wood are common.

SPHENOPHYLLALES.—The Sphenophyllales common to Missouri and Rhode Island are *Sphenophyllum cuneifolium* (Stb.) Zeil. and *S. emarginatum* Brgt., both of which are fairly widespread, *S.* (*Calamocladus ?*) *fontinalis* nom. nov., rather local in habit, and *S. majus* Bronn., which is occasionally found. *S.* (*Calamocladus ?*) *fontinalis*, nom. nov. (fig. 2) appears in the Missouri flora as "*Sphenophyllum* (*Asterophyllites ?*) *fasciculatum* (Lx.)" (**8**), a preempted name and therefore changed to a new specific designation from its resemblance to the modern water moss *Fontinalis*.

LEPIDODENDRALES.—The Lepidodendrales are evidenced among Rhode Island fossils principally by their leaves, fruiting cones, and roots. *Lepidophyllum missouriense* White (fig. 1) was regarded by WHITE as typical of Missouri alone, and its appearance in Rhode Island broadens the geographical range of the species. *Lepidostrobus jenneyi* White and examples of Sigillarioid leaves are found from Pawtucket, while *Stigmaria ficoides* (Stb.) Brgt. has appeared from several localities around Providence.

FILICALES AND CYCADOFILICALES.—The Filicales and Cycadofilicales common to Rhode Island and Missouri are greater in number and variety than any other plant group. They naturally divide into several classes, the first being characterized by variously incised and highly ornate forms as follows. *Eremopteris missouriensis* Lx. is occasionally found in Rhode Island, although rather common in Missouri. *Pseudopecopteris obtusiloba* (Brgt.) Lx. is somewhat abundant from the Pawtucket Valley Falls section. *Sphenopteris Brittsii* Lx., as found in Pawtucket, contains bristly, irregularly incised pinnules from a broad secondary rachis, while the Missouri forms are more regular. *Sphenopteris capitata* White and *S. chaerophylloides* (Brgt.) Presl. appear somewhat alike as illustrated in the literature of paleobotany; but specimens of the latter, as identified by LESQUEREUX, show fossils of a type found in abundance from the Portsmouth section of the Narragansett Basin, while *S. capitata* White is more sparsely represented in the state. *S. cristata* (Brgt.)

Presl. is mentioned in nearly all printed lists of Rhode Island fossil plants. Illustrations of this species from Europe, where it occurs



FIGS. 1–3.—Fig. 1, *Lepidophyllum missouriense* White; location, Valley Falls, R.I. (no. 376, Brown University Collection); fig. 2, *Sphenophyllum* (*Calamocladus?*) *fontinalis* Round; location, Portsmouth, R.I. (no. 394, Brown University collection); fig. 3, *Alethopteris serlii* var. *missouriensis* White; location, Pawtucket, R.I. (no. 731, Brown University collection); photographs natural size.

sparingly in Middle and Upper Coal (3), show great diversity of shape and size. Specimens from Rhode Island may be found which resemble either the lax or close European forms, and may be re-

garded as having varietal differences only from those in other parts of the world. Fragments of *Sphenopteris illinoiensis* White are occasionally found from the Providence section of the state, but can hardly be regarded as common. *Aloiopteris erosa* (Gutb.) White and *A. winslovii* White are frequently seen among fossils of the Narragansett Basin. They are likewise characteristic species of Missouri.

In contrast to the highly dissected Sphenopterids and allied genera are the Pecopterids, which are characterized by simple, entire pinnules attached to the rachis by entire bases. The *Pecopteris* group is well represented in Rhode Island, among the most common of these being the one called by WHITE *Pecopteris arborescens* (Schl.) Brgt., which he hesitates to designate as a new species (**8**). It is inclined to be slightly larger than typical *P. arborescens*, and agrees in size with ZEILLER'S *Pecopteris paleacea*. Specimens, however, show no more trace of the bristly rachis so characteristic of *P. paleacea* Zeil. than is described by the same writer for *P. arborescens* (Schl.) Brgt. (**6**). It appears to have been abundant in Lower Coal, Upper Coal, and Permian horizons of Europe (**3**). Another Pecopterid identified by LESQUEREUX from certain Rhode Island material is *P. candolleana* Brgt. While occasionally seen, it is not found in as great quantities in the state as is the case with *P. arborescens* (Schl.) Brgt. Although this species is reported from the Upper Coal and Permian horizons of Europe, it is likewise not abundant (**3**). *P. dentata* Brgt., however, is very common in the fossil floras of both Rhode Island and Missouri; and its presence in Europe seems rather typical of Lower Coal, although it is found in Upper Coal and Permian (**3**). *P.* (*Asterotheca*) *hemitelioides* Brgt. is of frequent occurrence in the Narragansett Basin, especially around Newport. Its presence in Missouri is recorded with reservations (**8**). The form of *P. pseudovestita* White (**5**), characteristic of Rhode Island, appears much like *P. vestita* Lx. (**5**), except that hairs are not especially noticeable and the nervils are inclined to fork but twice.

The Alethopterids are fairly numerous in Rhode Island. While *Alethopteris ambigua* Lx. is occasionally seen, *A. serlii* (Brgt.) Goep. is rather common. *A. serlii* var. *missouriensis* White is found in the Pawtucket Valley Falls section of Rhode Island (fig. 3), and is an

interesting connecting link between the Narragansett Basin and Missouri floras, the variety having been thought typical of Missouri alone. WHITE states:

> The varietal distinction of this Missouri form, which I have thought might be of stratigraphic utility, must be regarded as tentative, the question of its survival or elimination depending on the results of further study of material from other portions of the American Carboniferous.

Two Neuropterids are common to Rhode Island and Missouri. *Neuropteris rarinervis* Bunb. has been taken from the Valley Falls mines in considerable quantities, iron having entered into the preservation of the plant in such a way that it appears as a brownish fossil on a background of black slate. *N. scheuchzeri* Hoff., the broad type, is found from Pawtucket, while the narrow form is common from Mansfield.

Occasional specimens of *Aphlebia* appear in the Narragansett Basin, among which *A. germari* Zeil. is a striking example. The specimens from Rhode Island are somewhat smaller than those figured from Missouri, however, although similar in shape.

CORDAITALES.—The only representatives of this class which have appeared thus far in the Narragansett Basin are the Cordaitales. Among these, *Cordaites communis* Lx., which WHITE finds difficult to distinguish from *C. borassifolius* (Stb.) Ung., is found to be fairly common in Rhode Island. The majority of specimens are imperfectly preserved, however, so that care is necessary to find the fine striae which characterize the species.

Summary of similar species

Taken as a whole, over 50 per cent of the Rhode Island fossil plant species are found also in Missouri. Since the Cherokee shales (from which the Missouri series was derived) are considered as belonging to Middle Pennsylvanian, probably Upper Westphalian in the nomenclature of Europe (4), there seems to be ample ground for concluding that the Rhode Island coal measures are akin to the Allegheny beds of Pennsylvania, the Cherokee shales of Missouri, and the Upper Westphalian of Europe.

139 SUPERIOR STREET
PROVIDENCE, R.I.

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EVAPORATION RATES IN A NORTH FLORIDA HAMMOCK

FRANK THONE

(WITH THREE FIGURES)

The term "hammock" is used in northern peninsular Florida to designate any tree community dominated by angiosperms, as distinguished from pinelands and cypress swamps. Common recognition takes account of two general types of hammock characterized both topographically and by their vegetation. A "low hammock" is a swamp forest, with *Nyssa biflora*, *Acer carolinianum*, and *Magnolia glauca*[1] dominant, their roots covered with standing water throughout most of the year. A "high hammock" is a ravine forest of mixed hardwoods, with species of *Quercus* and *Magnolia* dominant, on moist but well drained soil. These ravines are shallow, seldom more than 10–12 m. deep. Sinkholes with bottom drainage also support "high hammock" on their steep sides; in these a depth of as much as 30–40 m. may be reached. A third type of hammock is sometimes designated "oak hammock," consisting of evergreen oaks of the *Quercus virginiana* habit, on dry sandy soil.

A notable feature of the high hammocks is the relative scarcity of herbaceous and shrubby undergrowth. In the high hammocks the trees stand close together and their tops interlace in competition for light. Lianas abound, but other lesser plants find a place only in partial clearings and around the margins of the forest. Except for dead leaves the ground under the trees is bare, since apparently not enough sunlight falls through to nourish any smaller vegetation.

In both low and high hammocks part of the trees are evergreen and part are tropophytic, so that the canopy becomes somewhat thinner during the winter months, although of course it never approaches the degree of nakedness of a northern hardwood forest in winter and early spring. It was partly a desire to learn the influ-

[1] The nomenclature here followed is that of BRITTON, N. L., *North American trees*. 1908.

ence of this partial denudation on evaporation rates, and partly a curiosity as to the drought conditions that must be faced by broad leaved evergreens (for winter is the dry season in Florida), that led to the present study.

Terrain

The area selected is a small high hammock lying in the grounds of the Agricultural Experiment Station at the University of Florida, at Gainesville. The ravine runs almost due north and south; its bottom is about 8 m. below the level of the surrounding country. The soil is very loose and sandy, with a slight enrichment of humus.

The tree population is young and very mixed. *Quercus laurifolia* and *Magnolia grandiflora* predominate, but there are also considerable numbers of *Q. nigra*, *Q. virginiana*, *Hicoria alba*, *Celtis mississippiensis*, *Liquidambar Styraciflua*, *Magnolia glauca*, *Tilia pubescens*, etc. There are a few scattering pines, mostly *Pinus echinata* and *P. caribaea*. The larger trees stand densely on the eastern edge of the ravine, and extend out on the level ground for a short distance. In this upper part there are few trees of secondary size and no shrubs. Along the slopes of the ravine, however, the forest growth is open enough to permit an irregular second stratum of trees, consisting mostly of *Carpinus caroliniana*, *Crataegus* spp., *Morus rubra*, *Myrica cerifera*, and *Aralia spinosa*. A few shrubs also come in, such as *Callicarpa americana*, *Sambucus canadensis*, and *Sabal palmetto*. The chief lianas are *Smilax* spp., *Vitis cordifolia*, and *Rhus radicans*. A scattering display of ferns, a considerable growth of an escaped *Begonia* species near the brook, and on the drier slopes a small stand of *Galinsoga parviflora* from a weed filled fallow on the western edge of the hammock complete the picture.

Instruments and methods

To measure the evaporation conditions near the ground level, five radio-atmometric pairs of Livingston standard spherical atmometer cups were set up on an east-and-west transect of the ravine, the cups in each instance being about 20 cm. above the surface of the ground. Station 1 was located at the boundary between the hammock and the fallow field on the west. Station 2 was about 15 m. to the east of Station 1 and about 1 m. lower, in a thin stand of

elderberry bushes. Station 3 was placed in the most moist and shady spot that could be found, on springy ground, under a dense stand of elderberry about 1 m. above the level of the brook at the ravine bottom. Station 4 was erected in a partial clearing near the top of the eastern slope of the ravine, and Station 5 some 20 m. to the east, on the densely shaded, plantless floor of the groove.

A vertical series of radio-atmometric pairs of cups was also operated, to measure the evaporation conditions of the higher aerial levels. Station I was hung by means of a light rope over the limb of a giant pine tree above the general level of the foliage canopy of the grove; the height is estimated at about 18 m. Station II was placed in containers nailed to the trunk of a tree in the hammock, at a height of about 4m. Station III was identical with Station 5 of the ground level series.

It was planned originally to operate the atmometers continuously from mid-October until the end of April, but a severe freeze coming unexpectedly during the first week in January wrecked the first set of cups, and continued cold weather during the remainder of that month made operation inadvisable. After operation was resumed, threats of cold waves made several shorter interruptions necessary during February. It is believed, however, that sufficient data have been accumulated to be of some value as an index to winter evaporation rates in this region.

It is much to be regretted that circumstances did not permit the securing of parallel data on the water-supplying power of the soil. Figures on evaporation rates alone are admittedly incomplete, giving only one-half of the story, but this defect may be somewhat mitigated in the present instance by the fact that casual observation showed that the soil in all parts of the area studied always carried available water close to the surface.

Discussion

The first thing noticeable about the graphs is their lack of any definite indication of a seasonal march of evaporation rates. General evaporation rates were higher in November than in October; higher in March than in April. Some such result as this of course was only to be expected in a region of equable winter climate. Could the unfortunate hiatuses due to the abnormally cold midwinter weather

have been avoided, it is doubtful whether the data for this period would have been materially different. The periods of low evaporation, notably the one in December, correspond generally with spells

FIG. 1.—Mean daily rates of evaporation in milliliters from standard spherical black and white atmometers in ground level transect series: black columns indicate simple atmometric effect; white extensions indicate increased evaporation due to direct insolation; absence of white extension indicates identity in reading of black and white instruments; in a few instances the reading of the black was less than that of the white.

of cool, foggy weather. The general evaporation rates seem to be high enough to indicate that winter, a season of scanty rainfall in Florida, must be a real drought period, for which the deciduous habit

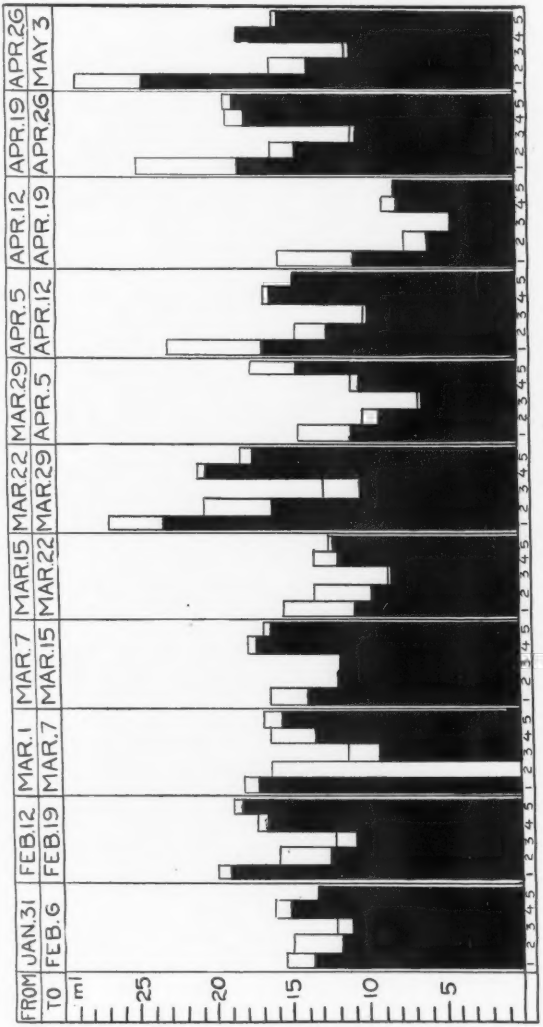

FIG. 2.—Continuation of fig. 1

of some of the trees, and the semixerophytic structures of others, are apparent adaptations.

Results ascribable to influences of topography are entirely ortho-

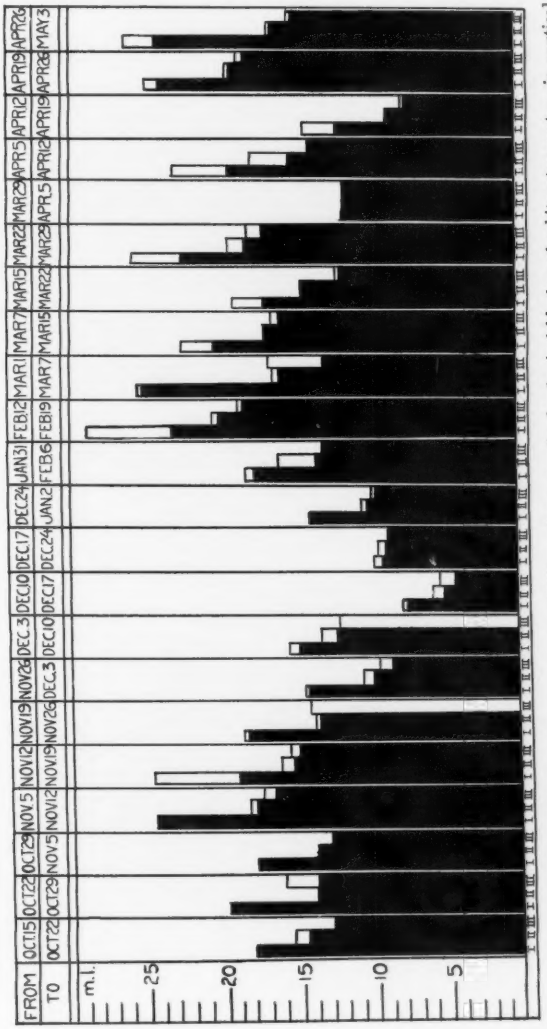

FIG. 3.—Mean daily rates of evaporation in milliliters from standard spherical black and white atmometers in vertical "aerial" series; conventions as in fig. 1.

dox. In figs. 1 and 2, each set of weekly curves might almost constitute a fair profile of the transect along which the stations were arranged, with Station 3 at the bottom of the ravine.

The really interesting feature about the data here presented is the very slight radio-atmometric effect observed at stations under the trees, even during the period of maximum denudation. The only station where the readings of white and black bulbs differed at all significantly was Station 1, situated in the open fallow field, where the added evaporation due to direct insolation amounted in most instances to between 20 and 30 per cent. At all stations sheltered by the trees the differences were sporadic and mostly insignificant; in a few instances there was even a slight excess of evaporation from the white cups. When this situation in partially evergreen woods is contrasted with that found by the writer in a deciduous forest in central Illinois,[1] where there was a high radio-atmometric effect in early spring that disappeared as soon as the leaves developed, the importance of the foliar canopy in reducing the influence of sunlight on evaporation rates on the forest floor becomes strongly apparent.

The results from the vertical series of stations (fig. 3) are also fairly normal, the evaporation rates bearing a direct relation to the distance above the ground. The excess of the evaporation rates in the air above the general treetop level over that beneath the foliar canopy was perhaps not as great as might have been expected, but it was always quite definite. The relatively insignificant radio-atmometric effect at Station I, high above the treetops, is somewhat anomalous, especially when compared with that at the ground Station 1, in the fallow field. This is probably accounted for by the fact that it was impossible to hang this station so that it could get the full benefit of the afternoon sun.

The writer is indebted to the Department of Biology of the University of Florida for facilities used in pursuing this study, and to the Department of Botany of the University of Chicago for the loan of apparatus.

SCIENCE SERVICE
WASHINGTON, D.C.

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[1] THONE, FRANK, Ecological factors in region of Starved Rock, Illinois. BOT. GAZ. 74:345–368. 1922.

SIGNIFICANCE OF TRACES OF ELEMENTS NOT ORDINARILY ADDED TO CULTURE SOLUTIONS, FOR GROWTH OF YOUNG ORANGE TREES[1]

A. R. C. Haas and H. S. Reed

(with six figures)

The purpose of this paper is to call attention to the fact that long continued use of certain nutrient solutions, commonly considered complete, may produce injurious effects which can be removed by the addition of traces of elements ordinarily considered unessential for plant growth. Students of plant nutrition who have employed cereals may have failed to encounter this difficulty, because the seeds, or the inevitable impurities of the chemicals, or the solubility of the containers have supplied the quantities of these elements necessary for short periods. Investigators in this field of experimentation have frequently ascribed the deleterious action of solutions to the toxicity of the distilled water employed. As will subsequently be shown, the deleterious action of the nutrient solutions used in this experiment was not due to traces of the heavy metals, or to volatile organic compounds, because all water was carefully treated with carbon-black, a powerful absorbing agent.

In the course of experiments on the effects of salts upon the growth and composition of orange trees, it was found that a characteristic type of injury usually appeared after 18–24 months. There is no evidence that the bad results were due to an accumulation of materials in the sand cultures, because the containers were well drained and the cultures were brought to their optimum moisture content with distilled water before the first addition of the nutrient solution. As each later supply of nutrient solution percolated downward through the sand, it displaced practically an equal volume of the old solution. Moreover, the harmful effects on the trees were overcome, not by the use of materials of greater purity, but by the addition of something previously omitted.

[1] Paper no. 145, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

It was found that every orange tree (several hundred in all) in sand cultures in asphalted galvanized iron cans that received culture solutions made with distilled water showed symptoms of decline, while orange trees in large tank cultures of sand receiving a culture

FIG. 1.—Orange tree showing initial stages of injury: tree grew in sand culture which received "complete" nutrient solution; reflexed leaves and leafless shoots on right of picture; following addition of "*A–Z*" to nutrient solution, all affected leaves shed and normal growth resumed.

solution made with tap water showed no decline. The injurious symptoms were produced alike, whether the nutrient salts were dissolved in ordinary distilled water or in distilled water treated with "Elf" brand carbon-black.

Fig. 1 shows the beginning stages of decline in a young Valencia

orange tree which had received Hoagland's solution in sand culture before remedial measures were taken. A few of the shoots had been defoliated, and such shoots usually died back to the end of the preceding growth cycle. Trees which received unfavorable salt addi-

FIG. 2.—Young orange tree showing advanced case of injury: tree grew in sand culture two years and received culture solution containing 500 p.p.m. sodium as sodium sulphate; later the leaves here shown were shed, but normal new growth was produced by adding "*A–Z*" to nutrient solution.

tions in their culture solutions developed the decline more rapidly than those which received Hoagland's solution. Fig. 2 shows the more advanced injury of a Valencia orange tree which grew in a sand culture two years with a culture solution containing 500 p.p.m. sodium as sodium sulphate. The injured leaves curled downward

along the midrib (fig. 3). The leaves were pale yellowish green on the upper side, and were marked with numerous spots which on the lower side seemed to be oil glands having a faded appearance. Frequently the center of such spots took on a resinous appearance (fig. 4).

FIG. 3.—Orange leaves which were recurved and show the thick veins, many of which had split open.

In addition to the curling and spotting of the leaves, many of them became corky and split along the veins. Fig. 5 illustrates the extent to which such vein injury may proceed. The veins seem to become riblike and extend well above the surface of the leaf, giving the intervenous region a shrunken or dried appearance. Seedlings of Florida sour orange grown in crocks of sand in the glasshouse also

showed such effects after four or five years. Leaves are shed prematurely once the veins have become split and corky.

When the decline became severe many of the leaves were shed, followed by a new growth, although the new leaves usually fell prematurely. The trees were grown in large containers and were not root bound. The sand was kept at optimum moisture content.

FIG. 4.—Orange leaves containing yellowish spots whose centers often had resinous exudations.

As the injury progressed, and after many of the younger cycles of growth had died, groups or clusters of buds (multiple buds) were produced in the leaf axils or above the former leaf scars, but none of them seemed able to develop (fig. 6). It was observed that the trunks of most of the trees which received large amounts of calcium chloride or calcium nitrate in their culture solutions in sand cultures showed considerable gum exudation, but this symptom was absent in later cultures where the deficiencies in the solutions had been supplied.

Since the nutrient solutions made up with tap water produced

healthy growth, the first thought was that the tap water contained something that the distilled water lacked. Furthermore, the trees used were budded stock, and when placed in the sand cultures were pruned back to a short piece of trunk and root, and the symptoms made their first appearance during the second year's growth when presumably the supply of constituents originally present in the trunk or root was depleted.

FIG. 5.—Orange leaves whose midribs and veins were greatly thickened and in many cases split open.

Since many of the older trees were beginning to show symptoms of a possible deficiency, the chief concern at the time was to remedy this situation, and then later to ascertain just what constituted the deficiency. A suspension, called for convenience "*A–Z*," was added to the culture solutions or to the distilled water applied to the sand cultures, so as to give a concentration of 0.2 p.p.m. of Al, I, Ti, Br, Sr, Li, Mn, B, and NH_4 respectively. The salts employed were aluminum sulphate, potassium iodide, titanium sulphate, potassium bromide, strontium nitrate, lithium nitrate, manganese sulphate, boric acid, and ammonium nitrate. Within a week no further curling of leaves occurred, although all badly curled leaves eventually

were shed. New growth was soon in evidence, and in a few weeks none of the symptoms of deficiency remained.

These results harmonize with those of other investigators (1, 2, 3, 4, 5, 6) who have found that certain of the preceding elements are actually required for the successful growth of plants.

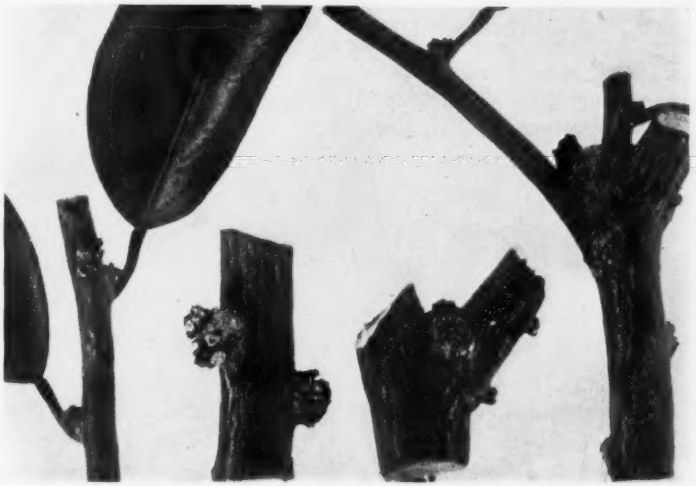

FIG. 6.—Pieces of orange shoots from injured trees on which there had been a formation of multiple buds.

At present it has not been discovered which of these ions was responsible for the prompt improvement of the trees, nor do we know that all of the symptoms were due to the deficiency of only one ion. A more detailed investigation of the problem is under way.

CITRUS EXPERIMENT STATION
RIVERSIDE, CAL.

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CHROMOSOME NUMBERS IN BUCKWHEAT SPECIES[1]

KARL S. QUISENBERRY

(WITH PLATE VI AND SEVEN FIGURES)

Very little cytological or genetical work on buckwheat has been reported in this country. This is probably due to the fact that the crop is one of minor importance, usually being grown on the poorer soil, since it does not compete with the important cereals on the better soils. Because of the possibility of starting a rather extensive inheritance and improvement project on this crop, it was felt desirable to learn something of the chromosome numbers in the various species, in order to obtain some indication of what might be encountered in the way of sterility of interspecific crosses.

It has been shown by various workers that the chromosome numbers of the several species of wheat, oats, and barley vary in multiples of a given number. The eight species of wheat, for example, fall into three groups with haploid chromosome numbers of 7, 14, and 21 respectively. In interspecific crosses considerable sterility is encountered, due in part to the differences in chromosome numbers. As a rule the greater the difference in chromosome numbers the greater the degree of sterility.

Materials and methods

According to LEIGHTY,[2] there are two, and possibly three species of *Fagopyrum*. The varieties Japanese, Silverhull, and Gray belong to the species *F. esculentum*. The first two varieties are the more important from a production standpoint, in this country. In some of the more or less mountainous regions Tartary buckwheat, *F. tartaricum*, is grown under various varietal names. In general, the seeds of Tartary buckwheat are much smaller and less angular than those of Japanese or Silverhull. It is also interesting to note that several, if not all of the varieties of Tartary buckwheat are highly self-

[1] Scientific Paper no. 23, West Virginia Agricultural Experiment Station, Morgantown, W.Va. Approved by H. G. KNIGHT, Director.

[2] LEIGHTY, C. E., Buckwheat. U.S. Dept. Agric. Farmers' Bull. 1062. 1919.

fertile, setting seed abundantly under glassine bags. Varieties of *F. esculentum*, on the other hand, are quite highly self-sterile. The third species is *F. emarginatum*, which, according to LEIGHTY, is not known to be grown pure in this country. In this type the angles of the seeds are extended and form wide margins or wings. Some workers feel that this type or species should be considered as a variety of *F. esculentum*.

Studies were made on Japanese and Silverhull belonging to *F. esculentum* (C. I. 91), Notch Seeded belonging to *F. tartaricum*, and on one sample of *F. emarginatum*. Root tip material was taken from seeds which had been germinating between blotters for 36–48 hours. In the case of the Japanese variety, some plants were grown in the greenhouse in order to obtain pollen mother cells from which to make chromosome counts in the haploid condition.

The material was killed with Allen's modification of Bouin's fluid, commonly known as B-15, and run through the regular paraffin method. In order to obtain anthers which were in the proper stage to give pollen mother cells, all buds killed were first examined to determine their stage of development. The method was to remove some anthers from buds at the base, center, and tip of the raceme branch, and mount these by Belling's method. As a rule the anthers from the tip of the raceme branch showed stages too young, while the base might show anthers containing pollen grains, since the inflorescence of buckwheat is indeterminate in habit of growth. The entire raceme branch was killed and imbedded, assuming that some buds would be in the right stage. Technique was not developed whereby chromosome counts could be made by Belling's method, due in part to the fact that the chromosomes are very small. Root tip sections were cut 5 μ thick, while the sections of pollen mother cells were cut 7.5 μ. Haidenhain's iron-alum haematoxylin stain was used.

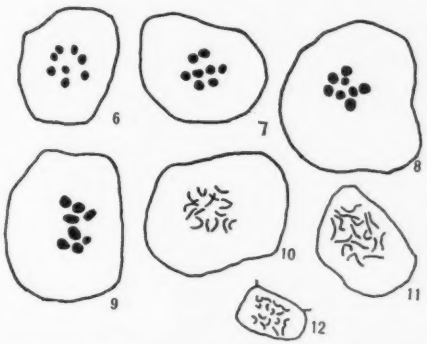
The photomicrographs were taken under a Bausch and Lomb 2 mm. immersion objective having a numerical aperture of 1.25. A daylight filter was also used to aid in obtaining definition.

Results

In the varieties and species studied no differences in chromosome numbers were found. In all cases the diploid chromosome number

obtained was sixteen. In the pollen mother cells from Japanese, counts were obtained showing a haploid number of eight. The counts obtained on Silverhull and Japanese agree with those reported by STEVENS.[1] Figs. 1–5 show photomicrographs of some of the material, figs. 1 and 2 being sections from pollen mother cells of Japanese. Fig. 3 shows the diploid chromosome number for Japanese, while figs. 4 and 5 are from *F. emarginatum*.

STEVENS reports that in the anaphase of the heterotypic division the eight chromosomes of a short styled plant tend to be arranged



FIGS. 6–12.—Figs. 6, 7, pollen mother cells from same anther of Japanese; figs. 8, 9, pollen mother cells from short style plant of Japanese; fig. 10, cell from root tip of Notch Seeded *F. tartaricum;* fig. 11, cell from root tip of Japanese; fig. 12, cell from root tip of *F. tartaricum* (C. I. 91); ×2300.

with six in the peripheral ring and two in the middle; while in the long style form the arrangement is seven in the peripheral ring and one in the middle. From the results of the investigation here reported no such conclusion could be drawn. In fig. 6 the arrangement may be considered as having seven in the peripheral ring with one in the middle; while in fig. 7 it may be considered that there are six in the peripheral ring and two in the middle. Both cells are from the same anther of a plant of unknown form of style. Figs. 8 and 9 are drawings from cells of different short style plants of Japanese. It would appear from these results that no definite arrangement of the

[1] STEVENS, N. E., Observations on heterostylous plants. BOT. GAZ. **53**: 277–308. 1912.

chromosomes occurs in the heterotypic metaphase of the varieties studied.

No consistent variations in size of chromosomes were found within a given cell. In the drawings the differences in size are due to the fact that only parts of the chromosomes are included in the section.

The writer takes this opportunity to acknowledge the valuable advice and criticism offered by Dr. FRED GRIFFEE of the University of Minnesota, under whose direction the work was done.

UNIVERSITY OF WEST VIRGINIA
MORGANTOWN, W. VA.

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EXPLANATION OF PLATE VI

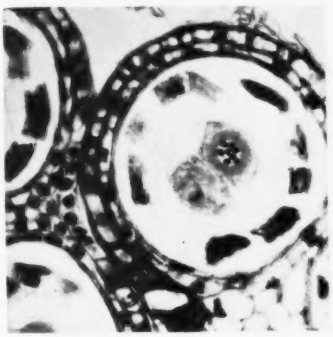
FIG. 1.—Pollen mother cell from Japanese, showing haploid number of 8.

FIG. 2.—Pollen mother cell from short style Japanese plant, showing haploid number of 8.

FIG. 3.—Chromosomes in cell from root tip of Japanese, showing diploid number of 16.

FIG. 4.—Chromosomes in cell from root tip of *F. emarginatum*, showing diploid number of 16.

FIG. 5.—Chromosomes in cell from root tip of *F. emarginatum*, showing chromosomes in late metaphase.



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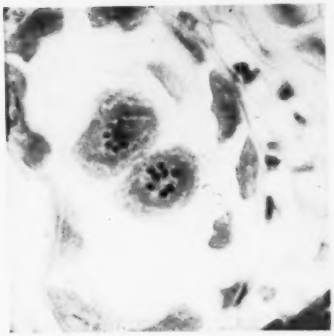

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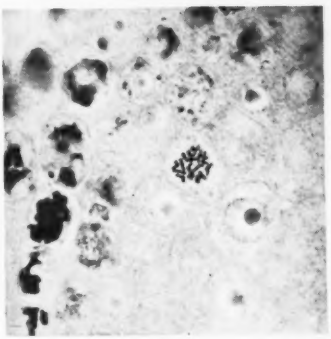

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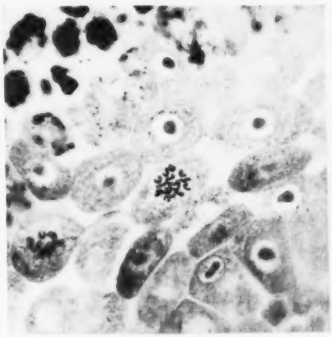

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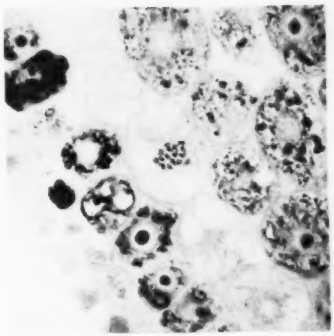

5

QUISENBERRY on CHROMOSOME NUMBERS

DUNE FORMATION BY PINE BARREN PLANTS

ARTHUR PIERSON KELLEY

(WITH TWO FIGURES)

Topography

Northern New Jersey is a region of glaciated hills, while the southern part of the state is a region of undulating sands. The northern half is clothed with deciduous forest, while the major part of the southern half is so copiously set with pines that it has long been called the Pine Barrens. The forest floor of the Barrens is not level, but is ridged and hollowed in an apparently schemeless way. The topography is much like that of the gray dunes beside the sea, old dunes which have become fixed and stable and overgrown with matted *Hudsonia* and tangled thickets of oak and catbrier.

There are hills in the Pine Barrens, as around Whitings, where an elevation of 300 feet is reached, but these have had a rather different history, being apparently the remnants of land of greater age (**8**). The dune hills along the coast are the result of wind and wave action, as described by such writers as GERHARDT (**5**) for Germany, COWLES (**3**) for the United States, and COCKAYNE (**2**) for New Zealand. These dunes take the form of long ridges or chains extending parallel to the coast from which the sand is derived. There are areas, however, upon which are found hummocky hills scattered in endless profusion, especially in places which have been subject to dune action for a long time. Concerning such hills COCKAYNE (**1**) states:

> Sandhills not forming chains may be either portions of such separated by wind action, or they may have originated directly on a sand-plain, or elsewhere, after the primary hills were destroyed or had wandered on. Sand-binding plants are chiefly responsible for the origin of these secondary hills.

Vegetation

Sand-binding action of plants seems to be responsible for the development of the Pine Barren hillocks. The plants of the Barrens have received much attention, and only the broadest ecological

groupings need be recalled here. *Pinus rigida*[1] is the facies of the Barrens, but there are other trees present, such as *P. echinata*, *P. virginiana*, *Quercus stellata*, and *Q. marilandica*. *Q. ilicifolia* and *Q. prinoides* form bushy undergrowths on open areas among the pines, with ericaceous shrubs, as *Neopieris mariana* and *Gaylussacia baccata*. The ever present *Pteridium aquilinum* and *Baptisia tinctoria* cover wide areas, while an acid-loving consociation of perennial herbs is scattered to copious in the pine needle litter under the trees: *Fissipes acaulis* (in Middlesex County), *Chimaphila maculata*, *Pyrola rotundifolia*. In open spaces *Arenaria caroliniana*, *Tithymalopsis Ipecacuanhae*, and *Pyxidanthera barbulata* spread upon the sand, while *Hudsonia ericoides* (in Middlesex County *H. tomentosa*) forms broadly spreading mats.

Formation of scattered hills

The forest floor and the open spaces in the forest, then, are rather well covered with a carpet of vegetation or of vegetable remains. Even under the needle litter of the pines the sand is kept moist and secure from the wind. When a plant dies the sand beneath is exposed, for but little leafage has accumulated beneath the impoverished branches. The winds pick up the loose sand, and, when the breeze blows fresh, a trough is quickly scooped into the surface and the plants are undermined. This sand is then borne onward, scouring pine branches and trimming off fascicles which oppose its progress. It is finally deposited against some obtruding object and heaped into a small pile.

Trees of the Pine Barrens produce basal whorls of branches (fig. 1). This fact, while remarked by STONE (11) in *Pinus rigida*, does not seem to have been emphasized by any writer on the Barrens. It would appear to be a response to the greater intensity of light reflected from the sand, and a Pine Barren tree, even as a sapling, may be excurrent at the base and deliquescent at the top. The pines especially produce bushy growths upon the sand, which at first sight seem to be seedlings, but closer inspection shows that they are only upgrowing tips of branches. Such branches have not been found

[1] All specific names are in accordance with Britton's *Illustrated flora*, 2d. ed.

rooting although covered with sand, but rooting of coniferous branches so placed has been mentioned (6).

Very gradually the basal branches are covered with slowly drifting sand, the ends continuing growth upward, as MACDOUGAL (7) noted in the Colorado desert, and COCKAYNE (2) in New Zealand dunes. Thus a basin is developed with the trunk in the center. A

FIG. 1.—*Pinus rigida* with basal branches; ground covered with snow

stray juniper "berry" or an acorn, as well as pine seeds drop in among the thickened branch ends, and seedlings thus develop, aiding in building the cone. Finally the original tree dies and the saplings continue its enlargement, with a resultant hill upon which frequently stand junipers and oaks. These hillocks are the antithesis of those noted by COWLES (3), which were the result of wind erosion, although some of the Pine Barren hills are the result of such erosion.

Formation of dunes

Not only hillocks are formed but long ridges which are really dunes, where pine forest meets deciduous forest. The Pine Barrens

extend northward into Monmouth County, while isolated patches exist in Middlesex County, one tiny area being on the terminal moraine of the last glacial advance. These isolated areas possibly represent the outer limits of an older Pine Barren area which has been and is being invaded by oak forest, which in itself is subclimax to beech forest. In one area near Spotswood, the two forests are so

FIG. 2.—Long dune where pine barren meets oak forest; ground covered with snow

arranged that the prevailing west wind sweeps first through the pine forest with its scattered trees, and then into the more copious growth of the oak forest. At the juncture a dune of from a few to twenty feet high has developed, as shown in fig. 2.

Earlier records of coniferous dunes

Coniferous dunes have been recorded from a number of places. On Cape Cod, plant succession on dunes was traced by WESTGATE (12), although he did not investigate the effect of plants on their development; *Pinus rigida* was noted as a subclimax stage to oak-beech forest. A coniferous dune was found by HARVEY on Cape Bre-

ton Island, while STOMPS (10) noted that coniferous forest usually develops on windward slopes and summits of Michigan dunes. In the same region COWLES (4) found coniferous and oak dunes covered with *Pinus banksiana* and *Quercus tinctoria* respectively. Miss SNOW (9) speaks of Delaware pine dunes as being antecedent to the present active dunes, "for the active crest shows knobs still held by pines, and the dead trunks falling on the windward side."

The Pine Barren hills seem to be what COWLES (3) calls "dunes of slow growth." These are "formed in older sands by less furious winds and different vegetation." *Juniperus sabina procumbens* was found to be a dune former within moderate limits, but pines were unable to withstand the advance of active dunes. In the New Jersey Barrens, however, dune action is so slow that the pines are able to keep pace with the sand deposition.

RUTGERS UNIVERSITY
NEW BRUNSWICK, N.J.

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INFLUENCE OF SALT UPON GROWTH RATE OF ASPARAGUS[1]

WILLEM RUDOLFS

(WITH TWO FIGURES)

Introduction

In another paper[2] the results of a study of beans grown under definite conditions as to temperature and humidity showed a decided advantage when the plants were grown from heavier seeds than when they were grown from lighter seeds. The effect of a stimulant upon the growth curve seemed of decided interest.

In the course of an investigation regarding the effects of common rock salt on plant growth, experiments were made with asparagus. ROBERTSON'S[3] formula, considering growth as an autocatalytic chemical reaction, was fitted to the observed data in the construction of growth curves:

$$\log.\frac{x}{a-x}=K\ (t-t_1)\ .$$

In this equation a is the final size of the plants; x is the size of the plants at time t; and t_1 is the time at which the plants have reached half their final size, or when $x=a/2$; and k is a constant. It was thought that a comparison of the curves for plants grown under the influence of different amounts of salt would perhaps throw light upon the question as to that part of the growth cycle upon which salt (and possibly other fertilizers) exerts its greatest influence.

Experimental results

The experiments with asparagus were conducted on the horticultural farm at the New Jersey Agricultural Experiment Stations.

[1] Paper no. 317 of the Journal Series, New Jersey Agricultural Experiment Stations, Department of Soil Chemistry and Bacteriology.

[2] RUDOLFS, W., Influence of temperature and initial weight of seeds upon the growth rate of *Phaseolus vulgaris* seedlings. Jour. Agric. Res. **26:** 537–539. 1923.

[3] ROBERTSON, T. B., Further remarks on the normal growth of an individual, and its biochemical significance. Arch. Entwick. Mech. **26:** 108–118. 1908.

Plots were laid out in the middle of a field on which asparagus had been growing for two years. These fields, and subsequently the experimental plots, consisted of an equal number of rows running east and west. The area is level, and the soil is a Sassafras loam. The duplicate plots consisted of blocks comprising an average of eighty plants. In addition to approximately ten tons of stable manure and one ton of poultry manure per acre, applications were made of 150, 300, and 500 pounds of common rock salt respectively, and again in the following year these amounts of salt were applied in addition to ten tons of stable manure and one ton of poultry manure per acre. The first year two cuttings were made. Seven days after the last cutting, counts of the numbers of plants and stems per plant, and measurements of the latter were begun and continued throughout the entire season at intervals of 7–10 days. During the second half of the growing season the asparagus beetle did some damage on all plots, resulting in dead tips of the stalks. Late in the season accurate measuring became extremely difficult on account of the entangling of the branches, and measurements were finally stopped, but counting of stems was continued at intervals until the end of the season.

Fig. 1 shows the fitted curves for the length of the stems. By the "check" curve, observed data are represented by small circles. The fitting of the other curves was about the same as in the case of the check. The stems were measured separately, but for the calculation of these curves these separate readings were added together and divided by the number of stems per plant, and each reading in the data, from which the curves are calculated, represents the average length of about eighty plants. The regular increase in the total length of stems per plant reached a maximum in the middle of the season. A second growth period commenced, following essentially the same curve as is indicated in the first part of the curves.

The curves for the number of stems produced are given in fig. 2. Cycles similar to those in the curves constructed from measurements of length are obtained. The increase in numbers of stems was as regular and consistent as the increase of total length of stems. In comparing the curves for the total length of stems with the curves for the total numbers of stalks, it is evident that the difference in total length is mainly produced by an increase in the number of

stems per plant. When the greatest possible length of the growing stems is reached in the middle of the growing season, the plants will produce new shoots giving rise to new stalks. An increase of stalks

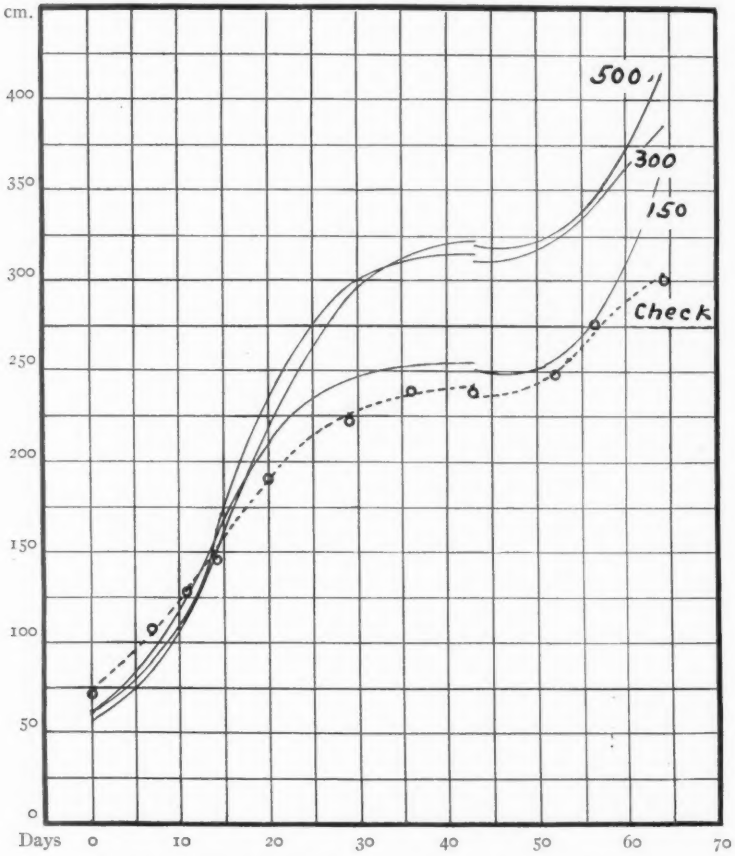

FIG. 1.—Growth rate of asparagus as represented by summated lengths of stems: plants receiving respectively none (checks), 150, 300, and 500 pounds of salt per acre. Curves show values obtained from averages of 80 plants. Apparent break of curve is due to necessity of fitting two successive growth cycles with different formulas. Data given in check curve illustrate closeness of fitting.

leads to an increase of storage food, and consequently to higher yields in the next season.

The influence of salt manifested itself mainly after the fourteenth day of measuring, that is, after three weeks of continuous growing.

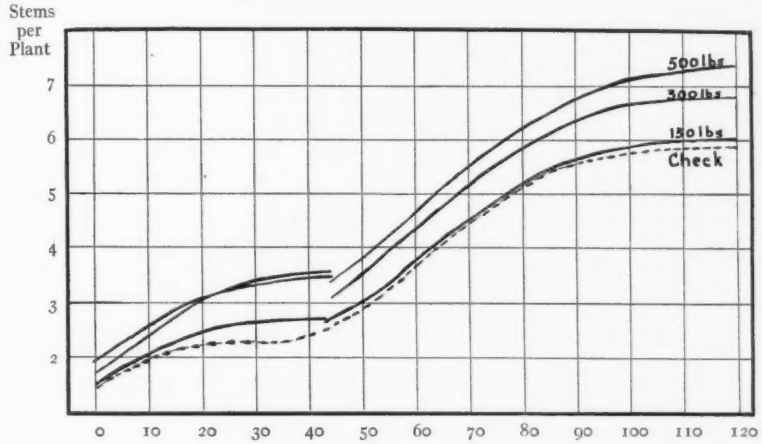

FIG. 2.—Growth rate of asparagus represented by numbers of stems per plant: curves show values obtained from averages of 80 plants.

This influence continued throughout the first cycle, and seemed to accelerate growth again in the course of the second cycle. From these curves it appears that salt is not merely a stimulant of growth at the beginning of the season, but continues to stimulate throughout the growing period of asparagus plants.

Summary

1. Experiments with common rock salt in addition to manure applications were conducted with asparagus in the field. Applications of 150, 300, and 500 pounds of salt were made for two years in succession. Measurements of the length of asparagus stems were taken, and the numbers of stems were counted at intervals of 7–10 days throughout the second season.

2. The asparagus showed two distinct cycles of growth in the season, and each cycle proceeded at a rate corresponding to an autocatalytic chemical reaction, producing an S-shaped curve.

3. Salt exerted a regular and comparable influence throughout the growing season upon the total length, and the number of stems of asparagus plants.

NEW JERSEY AGRICULTURAL EXPERIMENT STATION
NEW BRUNSWICK, N.J.

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A STUDY OF A MEXICAN RICCIA

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 363

M. ARLOUINE CHESEBROUGH

(WITH SIX FIGURES)

In October 1908, Dr. W. J. G. LAND found a species of *Riccia* growing at an altitude of about 2042 m., under a Nopal cactus on an exceedingly arid mountain side near Guanajuato, Mexico, a region the streams of which are so heavily charged with mineral salts that they are noticeably lacking in algae. These surroundings are so unique for this commonly hydrophytic or hydro-mesophytic genus as immediately to stimulate a desire to determine whether these plants showed any structural peculiarities, and, if so, whether these were of such a nature as to indicate any special fitness for growth in a particularly arid situation. Of this material, killed in the field and imbedded and stained in the ordinary way, LAND had already made a series of fifty slides. These he kindly lent to me for the present study.

The preparations available strongly suggest that the asymmetrical thallus is built from a single meristem initial, as shown in fig. 1. It lies well toward the ventral side of the thallus and cuts off segments, dorsal and ventral, sinistral and dextral. From the subsequent divisions of the dorsal segments is built the thick dorsal portion of the thallus. From the divisions of the ventral segments results the relatively small development of thin walled cells forming the ventral comparatively non-chlorophyllose portion of the plant. From the divisions of the sinistral and dextral segments the large wings are built. The cells in the region of the median line become rather elongate, and form a somewhat specialized region of food conduction.

The thicker dorsal part of the thallus is composed of exceedingly compact tissue arranged with great regularity, in the form of plates of cells separated by air chambers, deep clefts reaching to within one cell layer of the median line. These air spaces arise by internal

cleavage, as do the air chambers of *Riccia fluitans* and *R. natans* reported by BARNES and LAND.[1] Splitting normally occurs early in the development of the meristematic region, about three rows of cells from the margin, between the superficial cells and those immediately underlying them, and the split may soon break out to the surface, as shown in fig. 2. The position of the first splitting, and the fact that the clefts never extend to the median plane which lies between the ultimate products of the dorsal and ventral segments of the wedge-shaped marginal cells, show that the splitting progresses from below upward, and not as LEITGEB[2] states or as Miss HIRSCH[3] reports for *Riccia Frostii*, from above downward. This is shown in fig. 1. The plates of chlorophyllose tissue resulting from further division and growth of the dorsal segments, and separated by such simple clefts, constitute a thallus indicative of a rather primitive condition of thallus architecture, for food must pass down each row of cells almost to the median line and thence to the points of consumption, instead of passing by a more direct route. Likewise this type of incomplete splitting, resulting in plates of cells rather than in filaments of chlorophyllose tissue, represents an intermediate type of air chamber with regard to high specialization.

Marked degeneration of chloroplasts occurs in the outer cells of the thallus. As this degeneration progresses, the plastids break down into a mucilage-like substance which probably protects the plant from desiccation. After this disintegration of plastids, the walls of the outer cells are no longer distended by turgor, and they collapse and assume a more or less hemispherical or meniscus shape. Often adjacent cells of this row meet closely over the air chambers, closing them completely and retarding evaporation. In the older parts of the thallus the plastids in the layer of cells immediately below these show the beginnings of disintegration, and seem destined for the same fate as the outermost ones, upon the death of the latter (fig. 3).

In the region of the sex organ groove, which is completely closed,

[1] BARNES, C. R., and LAND, W. J. G., Bryological papers. I. The origin of air chambers. BOT. GAZ. **44**: 197. 1907.

[2] LEITGEB, H., Untersuchungen über die Lebermoose. **4**: 10. 1879.

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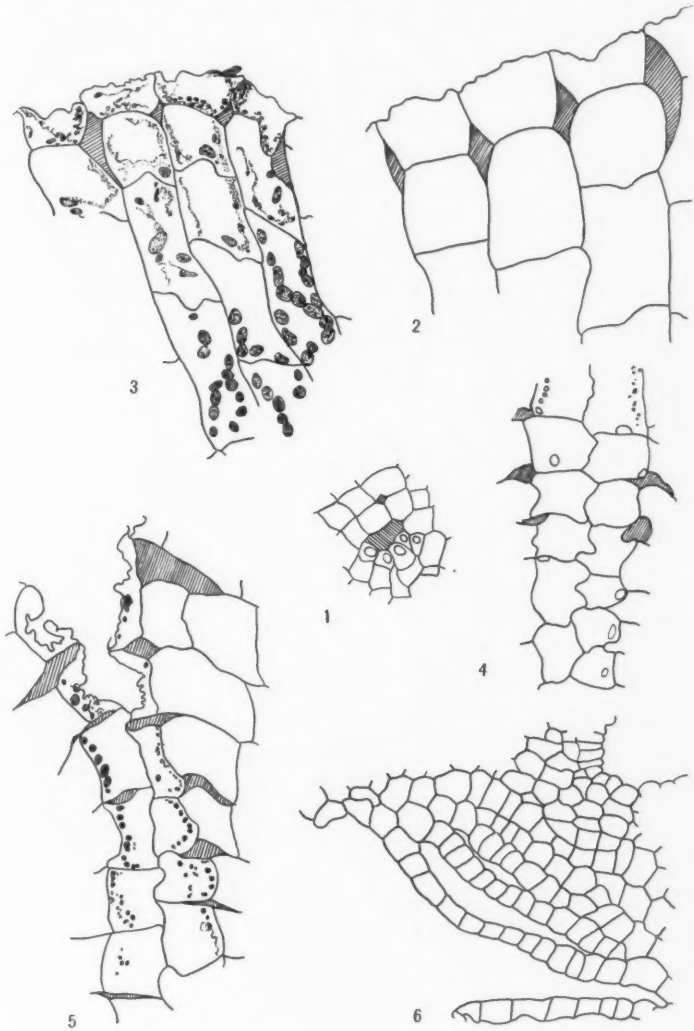
except at the front of the thallus, the cells forming the outer layer are large and rather thick walled. The outer cells of one wing are often fused with those of the other; in any case there is a very close



interlocking (figs. 4, 5). Probably this protects the delicate meristematic region and the developing sex organs from drying out. In all the preparations examined, the marginal cells at the base of the groove are turgid, and do not give the appearance of having been subjected to excessive lack of moisture. LAND reports that a slight amount of moisture was found in the groove in some plants cut open in the field.

The abundant scales, curving over and closely investing the meristematic region at the apex of the thallus, arise in the usual manner from surface cells on the lower side of the thallus. They probably function in preventing loss of moisture from the meristematic area and in affording protection from mechanical injury. These scales are shown in fig. 6.

As compared with the Marchantiaceae, the development of the mucilage hairs in these plants is very slight. This casts additional doubt on the correctness of the idea that these liverworts depend to as great a degree as some believe upon an abundance of mucilage to keep them from drying out in relatively arid situations.

In summarizing this study, therefore, it may be stated that structurally the thallus of this species of *Riccia* from an exceedingly arid Mexican mountain side possesses three features which are almost certainly of survival value in such an environment. They are (1) ventral scales which closely invest the growing point; (2) a tightly closed sex organ groove except at the front of the thallus; and (3) a row of superficial cells, the plastids of which break down into a mucilage-like substance, and the walls of which collapse upon the resulting lack of turgor, so that adjacent cells meet over the air spaces. Obviously these features not only serve to protect the plants possessing them from mechanical injury, but tend to conserve their moisture content, which in a dry situation is of major significance.

UNIVERSITY OF BUFFALO
BUFFALO, N. Y.

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BRIEFER ARTICLES

SHRINKAGE AND GROWTH IN PLANT STEMS

The retardation of the growth rate of stems during the day has frequently been noted, but the fact that there may be an entire cessation of growth, or even an actual shrinkage in length during the intense heat of midday or shortly thereafter, due to loss of water from the tissue of the stem through transpiration, is not so widely known. This paper records such an observation made on five different species of plants, four herbaceous and one woody.

BROWN and TRELEASE [1] record their observations on this, and also cite instances recorded in the literature. They observed at hourly intervals changes in the length of the stems of *Cestrum nocturnum*, a cultivated shrub, growing where it was exposed to severe conditions of light and temperature. They found a shrinkage of 0.5–2.5 mm. in the length of the stem during the middle of the day, and a recovery of the original length when the plant became shaded. The period of maximum shrinkage did not coincide with the period of greatest evaporation from a Livingston white spherical atmometer, but occurred several hours earlier. They believed that sunlight had a greater effect on the wilting of the plant and the shortening of the stem than the evaporating power of the air as measured by the white atmometer.

During the summer of 1924 observations were made on several plants whose runners stretched for many feet over the blazing white sand of the beach. The observations were made near Puerto Galera, Mindoro, Philippine Islands. It was a gently sloping area of fine white coral sand fully exposed to the sun from early morning until evening. The upper beach supported a sparse vegetation characteristic of the beaches of the Philippines. Many of the species of this beach vegetation send out prostrate stems or runners, which stretch over the sand for many feet, in the case of *Ipomoea Pes-caprae* for as much as 30 feet.

Measurements were made on five species, *Ipomoea Pes-caprae*, *Canavalia rosea*, *Wedelia biflora*, *Vigna marina*, and *Quisqualis indica*.

[1] Alternate shrinkage and elongation of growing stems of *Cestrum nocturnum*. Phil. Jour. Sci. **13**: 353–360. 1918.

An ink mark was made on the older portion of the stem where growth had ceased (usually 80–120 cm. from the tip), and the growing stem measured from this point to the extreme tip. This was done at 6:30 P.M. on the previous evening. The measurements were begun in the morning at 6:00 A.M., and only those plants were used which showed a normal growth during the night. The measurements were continued at hourly intervals throughout the day until 6:00 P.M. The final measurement was made at 6:30 A.M. the following morning to determine whether normal growth had occurred during the night. In some cases the handling of the plant incident to the measuring injured the delicate growing tip, resulting in the blackening and wilting of the injured portion. The day on which the measurements were made was a remarkably clear, hot day, with a brilliant sun and little air movement.

TABLE I

GROWTH MEASUREMENTS ON STEMS (GROWTH INCREMENT OR DECREASE OVER NEXT PRECEDING MEASUREMENT IN MM.)

PLANTS	APL 28	APRIL 29													APRIL 30
	6:30 P.M.	6:00 A.M.	7:00 A.M.	8:00 A.M.	9:00 A.M.	10:00 A.M.	11:00 A.M.	12:00 A.M.	1:00 P.M.	2:00 P.M.	3:00 P.M.	4:00 P.M.	5:00 P.M.	6:00 P.M.	6:30 A.M.
Ipomoea Pes-caprae	0	67	3	0	2	1	0	−3	0	0	6	7	2	6	46
Canavalia rosea....	0	12	0	1	0	0	0	0	−1	1	1	−1	0	0	3
Wedelia biflora....	0	10	0	0	0	0	0	−2	−1	0	0	3	2	1	5
Vigna marina.....	0	21	0	0	1	0	0	−1	−4	0	−3	4	−2	0	Broken
Quisqualis indica...	0	42	2	0	1	1	0	−1	0	0	2	3	5	0	19

The following reading of the environmental factors was made on a nearby beach, with the conditions of sand, vegetation, and sun similar to the beach where the measurements were taken. April 29, 1924: Livingston white spherical atmometer 41.6 cc. in 24 hours; this was one of the highest readings recorded during a period of over eight weeks. The air temperature was 84.5° F. at 5:00 P.M. No maximum was recorded during the day, but it was probably considerably above 90° F. in the shade (table I).

The growth during the night (from 6:30 P.M. to 6:00 A.M.) was considerable in all species and exceptional in *Ipomoea*, which increased 67 mm. in length. All of the plants showed very evident signs of wilting during the middle of the day. *Ipomoea* folded up its leaves with the upper side inward, while the leaflets of *Canavalia* and *Vigna* folded up in a similar manner and presented much less leaf surface to the sun and air. The leaves of *Wedelia* and *Quisqualis*, without these adaptations, became

very flaccid and wilted. They all recovered toward evening, beginning at about 3:00 P.M.

Ipomoea proved a very rapid grower, showing an increase in length up to 10:00 A.M., in spite of the great heat and water loss, and beginning its increase again at 3:00 P.M.; while during the night following the day of measurements it grew 46 mm. During the heat of midday it became 3 mm. shorter, and did not recover this shortage for several hours. The day's heat started early, resulting in almost no increase after 7:00 A.M. *Wedelia* grew none during the forenoon, shrunk 3 mm. at midday, and regained this from 4:00 P.M. on. The irregular record of *Vigna*, especially its shrinkage late in the afternoon, was undoubtedly due to injury while being measured, as became evident the next morning. In no case was the growth during the night following the measurements as great as during the night preceding them, probably due to disturbing the plant during measuring. The first elongation early in the afternoon was not true growth, but merely regaining the length which the stem had shrunken during midday. In accord with the finding of BROWN and TRELEASE, it was found that the greatest shrinkage occurred between 12:00 and 1:00 P.M., and hence did not coincide with the period of greatest evaporation from a Livingston white atmometer; also elongation began again at 2:00–3:00 P.M., when the rate of evaporation was still very high.—RAYMOND KIENHOLZ, *University of Illinois, Urbana, Ill.*

[*Accepted for publication March 6, 1926*]

CURRENT LITERATURE

BOOK REVIEWS

Manual of cultivated trees and shrubs

It is no small task to bring together a classified analytical critical description of nearly 2500 species, and as many differentiated varieties, representing over 400 genera and a quarter as many families. This is what REHDER has done in his manual of the woody plants known as hardy in North American parks and gardens.[1]

REHDER is unsurpassed in knowledge and experience in this field. For a quarter of a century he has clarified for himself and others the characteristics of woody plants through succeeding editions of BAILEY'S *Cyclopedia*, in which he has treated the greater number of such plants. The *Manual* into which his long experience has ripened now is literally a handbook, light enough to be carried afield notwithstanding its thousand pages of text.

Special features of the *Manual* are a double-columned five-page explanation of abbreviations of authors' names; an extensive list of works to which reference is made for illustrations; explanation of geographic and miscellaneous abbreviations; metric and duodecimal measurement scales; and a map of North America divided into isothermic or hardiness climatic zones. A synoptical key to natural orders and families claims five pages; and an analytical key to families and aberrant genera, based on customary taxonomic characters, occupies another five. The index to plant names, including extensive synonymy, occupies seventy closely set three-column pages, which may give an idea of the comprehensiveness of the book.

The descriptive contents of such a volume contrast noticeably with those of an ordinary guide to a regional flora, because on the one hand it is restricted to a fractional part of the families represented, and on the other hand it takes account of definable varieties outnumbering the species to which they pertain. For example, 29 genera of gymnosperms with 199 species are included, and monocotyledons are represented by only 9 genera and 56 species. Numerous families unknown in our native flora find representation, although usually in a small number of forms. As might be expected, the Schizopetalae stand out in prominence, with 60 families, to which half of the descriptive part of the book is devoted; the Gamopetalae with nearly half as many families (27) claim little more space than the single family Rosaceae; and the Apetalae with over half as

[1] REHDER, ALFRED, Manual of cultivated trees and shrubs hardy in North America exclusive of the subtropical and warmer temperate regions. 8vo. pp. xxxvii+930. New York: Macmillan Co. 1927.

many families (15) as the Gamopetalae average only two pages to the family, largely taken up by the oaks with 58 species. Among the most familiar and here outstanding families are the Caprifoliaceae (10 genera occupying nearly 50 pages); Oleaceae (11 genera, claiming only about half the space); Ericaceae (34 genera, about as extensively treated as the less varied Caprifoliaceae); Leguminosae (39 genera but averaging only a page to the genus); and, as would be expected, Rosaceae (48 genera, claiming nearly as much space as all of these other families together).

The author has been reasonably consistent in the matter of nomenclature, following international rules in the main, which will meet with warmer approval in some circles than in others. This will render comparison fairly easy with the *Cyclopedia of horticulture* and with one series of handbooks of our native flora, the former especially to be commended. Happily, intergeneric hybrids are designated by pseudo-generic names; and interspecific hybrids by pseudo-specific names, naturally with indication of accepted parentage. Minor forms are treated trinomially.

A request is modestly inserted for material and information that will enable later editions to be made better than the first. No doubt many improvements and additions will be brought to his attention; the author himself has added three pages of emendations. From the reviewer's viewpoint, no new feature is more desirable than the incorporation of keys based on summer and winter vegetative characters, because flowers are present for only a brief time each year if at all. For the preparation of such keys no more competent botanist lives than the author.—WM. TRELEASE.

Introduction to cytology

That a second edition of SHARP's book[2] should be needed so soon is proof that the work has had a wide range of usefulness. While WILSON's recent revision of his book on the cell has given considerable attention to plants, and is extremely valuable because it gives to botanists the interpretations of an able zoölogist, the botanist nevertheless needs a comprehensive treatment written primarily from the botanical standpoint. Naturally, this second edition has been improved and enlarged, and the author has doubtless profited by the advice and criticisms of those who have used the first edition. The number of pages and of illustrations has been increased, and also some of the previous figures which are retained have been improved.

Descriptions of mitosis, especially the reduction mitoses, have been thoroughly revised, and many of the new figures occur in this section. In regard to the structure of the chromosome, the author believes that a "chromonema" of some sort is probable, but its relation to the alveolized condition, seen so clearly in larger chromosomes, remains to be determined. The author suggests that this situation demands a further study of fixation. The reviewer would sug-

[2] SHARP, L. W., An introduction to cytology. 8vo. pp. xiv+581. *figs. 210.* New York: McGraw-Hill Book Co. 1926.

gest a more critical comparison of living and fixed material. The theory that the nuclear reticulum consists of a single substance (chromatin), rather than a series of chromomeres upon an achromatic linin, is discussed, and the "chromomeres" are interpreted as thick regions of the chromatic thread and not as chromomeres supported by another material.

In dealing with heredity, many changes have been necessitated by recent researches upon chromosomes in polyploid organisms and in hybrids. There is also new material on sex chromosomes and the relation of the chromosome theory to the metabolic theory of sex determination. There is a new chapter, with much new material, on gametogenesis, dealing with both plant and animal organisms. Chromosomes and also blepharoplasts receive attention here. In general, more attention is given to studies on living tissues, especially the achromatic figure and meiosis. Other sections which are more adequately treated in the second edition are those dealing with chromidia, chondriosomes, and cytokinesis.

It is evident that more attention has been given to LAMARCK and other French biologists in the development of ideas of the structure of organisms. The organismal theory is prominent in the histological treatment, especially in the discussion of the relation of cells to differentiation and other activities of protoplasm. The author seems dominated by the idea that the action of a system is not simply the sum of the action of its parts, but that the parts act as they do because of their relation to the rest of the system. Whether the theory is correct or not, it introduces an element of unity and affords a reasonable explanation of various phenomena.

In the new edition there is one very complete bibliography, arranged alphabetically, with a chronological grouping of the works of each author. This is a great improvement on the numerous fragmentary bibliographies of the first edition. The index is extensive and has catchwords and full face type for illustrations. It is hoped that the book will continue to improve with the rapid and multifarious development of the subject.—C. J. CHAMBERLAIN.

Anatomy of angiosperm seed

Another volume of the *Handbuch der Pflanzenanatomie*, under the general supervision of K. LINSBAUER, deals with the structure of the angiosperm seed. As projected, the series covers the whole field of the structure of plants, from the algae to the orchids, the various phases being assigned to various botanists. Since each part is published when the manuscript is ready, as in case of ENGLER'S *Pflanzenfamilien*, the parts do not appear in the sequence indicated by the general table of contents. In the complete table there are two series, general and special, and of these the first is subdivided into cytology, histology, and experimental anatomy; the rest of the work is also highly organized. Some idea of the scope of the subject and the standing of the men handling it may be gained from the titles of the five volumes devoted to cytology: *Cell and cytoplasm*, by LUNDEGÅRDH; *Plastiden*, by SCHÜRHOFF; *Pflanzenkaryologie*, by

TISCHLER; *Cell materials*, by RICHTER, NETOLITZKY, and MÖBIUS; and *Cell membrane*, by WISSELINGH. The rest of the volumes are also by men of high rank. The whole series is a useful, well organized combination of compilation and investigation by experts.

Volume X is by NETOLITZKY, on the anatomy of the angiosperm seed.[3] It includes much literature supplementing the scattered and incomplete accounts of this important structure. Unfortunately, QUISUMBING's investigation of the origin and development of the seed coat was overlooked, probably because the title of this work suggests that it deals only with gymnosperms.

The first part treats the ovule, integuments, nucellus, and embryo. Attention is given to the seed coat as an ecological entity, to the protective layers, and to the value of the seed coats in taxonomy and phylogeny. Most of the text and illustrations deal with the mature or nearly mature seed. In the second part the essential characters of the seed are given for most of the families, with citations of the more important literature closing the account of each family.

A very useful feature is a 13-page table, listing family by family some of the principal seed characters. Besides the usual bibliography, there is a second author index, giving the pages on which references are made to the work of each investigator. HOFMEISTER is referred to 65 times, and references to many others are numerous. There is an index to the genera of all the plants mentioned in the text, and also an extensive subject index.

This series of books, summaries of various phases of botany, largely editorial, but confirmed, corrected, and extended by experienced investigators in the different fields, should simplify and shorten the preliminary work of workers who need to know what has already been done in any particular subject. While the student would not be relieved of the necessity for consulting original sources, this series will at once put him into contact with most of the literature.—C. J. CHAMBERLAIN.

A New Zealand Manual

In 1906 CHEESEMAN published the first manual of the New Zealand flora, which was reviewed in this journal.[4] Soon after its appearance the advance in knowledge of the flora of these islands made a revision necessary, and on this the author was still working when he died at Auckland, in 1923. From his manuscript, from extensive notes, and from his published papers the revision has been completed by OLIVER, who assures us that his contribution consists only in editing the material with as few changes as possible.

In this edition[5] an addition of 192 species brings the total number to 1763,

[3] NETOLITZKY, FRITZ, Anatomie der Angiospermen-Samen. 8vo. pp. v+364. *figs. 550*. Berlin: Gebrüder Borntträger. 1926.

[4] BOT. GAZ. **42**: 495. 1906.

[5] CHEESEMAN, T. F., Manual of the New Zealand flora. 2d. ed. Edited by W. R. B. OLIVER. 8vo. pp. xliv+1163. Washington: W. A. G. Skinner, Government Printer. 1925.

comprising 159 pteridophytes, 20 gymnosperms, 400 monocotyledons, and 1184 dicotyledons. Five families possess over 100 species each. They are the Compositae with 261 species, the Filices with 141, the Scrophulariaceae with 138, and the Cyperaceae and the Gramineae with 123 species each. Some of the other large families, in order of size, are Umbelliferae, Orchidaceae, Ranunculaceae, Rubiaceae, Onagraceae, Epacridaceae, Boraginaceae, and Leguminosae. Among the genera with 20 or more species each are *Veronica*, *Celmisia*, *Coprosma*, *Olearia*, *Ranunculus*, *Cotula*, *Raoulia*, *Carmichaelia*, *Hymenophyllum*, and *Dracophyllum*. The endemic element of the flora is conspicuously large, consisting of 1329 species, or over 75 per cent of the whole. Of the species found also in other lands, 369 extend to Australia and 112 occur in South America.

An important part of the volume, and one particularly interesting to those living outside New Zealand, is a history of the botanical discovery and exploration of the region. This dates back to COOK's first visit in 1769–70, on which he was accompanied by the celebrated naturalist Sir JOSEPH BANKS. On COOK's second voyage he was accompanied by JOHN R. FORSTER and his son GEORGE FORSTER, and also by Dr. SPARRMAN, a former pupil of LINNAEUS. All of these men, who were botanists of ability, had the privilege of exploring virgin territory and attracting others to complete the work. In the present volume OLIVER has brought the botanical history of New Zealand down to 1924.

In addition to the main part of the manual, containing the usual keys and descriptions of genera and species, the volume contains a list of plants naturalized in New Zealand, an alphabetical list of Maori names of plants, a glossary, and a list of the published works of T. F. CHEESEMAN.—G. D. FULLER.

NOTES FOR STUDENTS

Relation of iron to chlorophyll development in growth of plants.—Iron is one of the essential elements for the growth of plants, because it is needed for chlorophyll development, but it is not known why it is needed for this process. A few years ago POLACCI and ODDO advanced the theory, based upon their own experiments and the work of WILLSTÄTTER on the chemistry of chlorophyll, that iron catalyzes the formation of pyrrole groupings which enter into the composition of the nucleus of the chlorophyll molecule. These workers state, however, that if pyrrole groups of a kind that the plant can use are supplied, then iron becomes unnecessary for the development of chlorophyll. They described experiments in which normal green plants were obtained, when suitable pyrrole groups but no iron were supplied.

DEUBER[6] has been unable to confirm the work of POLACCI and ODDO. Even in weak concentrations the pyrrole salt proved toxic and did not prevent chlorosis when iron was absent. All possibilities which may explain these divergent results were eliminated by experiments, except the factors having to do with the

[6] DEUBER, C. G., Can a pyrrole derivative be substituted for iron in the growth of plants. Amer. Jour. Bot. **13**:276–285. 1926.

differences in environment, but that the differences in the results obtained were not due to different environmental conditions was strongly indicated by limited experiments with a sample of the pyrrole salt used by POLACCI and ODDO in their experiments. This salt also proved toxic and did not prevent chlorosis when iron was absent.

It would seem that the question of the relation of iron to chlorophyll development remains yet to be solved.—S. V. EATON.

Ancient lotus fruits.—OHGA[7] has investigated the structural conditions of dormancy in some fruits of Indian lotus (*Nelumbo nucifera*), said to be at least several centuries old, which proved to be still viable under certain conditions. In a previous paper, published in 1923, the announcement of their discovery was made. In the present paper the structural details are presented. The statement is made that "they appear to be the oldest viable seeds thus far known." The fruits were found in a prehistoric peat bed in South Manchuria. More than 200 of these ancient fruits were tested for viability and all of them germinated. A detailed account of their structure is presented, and the conclusion reached that their prolonged viability is due to their burial in the soil and their hard coats, which are impermeable to water. Experiments showed that water cannot enter unless the fruit coat is removed or broken up by some mechanical or chemical treatment. The most satisfactory solvent was found to be sulphuric acid. Even when treated for 24 hours with concentrated sulphuric acid, the embryo was not killed.—J. M. C.

Gametophyte and embryo of Asplenium.—FREER[8] has investigated *Asplenium angustifolium*, a species of wide range, but apparently disappearing. The spores germinate slowly, requiring ordinarily about a month. The apical cell formation differs from the usual method in this group of ferns, the first division of the terminal cell being longitudinal instead of oblique, and both of the resulting cells dividing transversely. The protonemal filament is usually only three or four cells long when the terminal cell divides. The gametophyte is regularly heart-shaped. The archegonium develops as usual, with two exceptions: the first division of the inner cell sometimes precedes and sometimes follows the formation of the "chimney foundation from the cap cells"; the division of the central cell may precede or may follow that of the basal cell.—J. M. C.

Longevity of pollen.—HOLMAN and Miss BRUBAKER[9] have conducted some extensive experiments on the longevity of pollen, testing 50 species of angio-

[7] OHGA, ICHIRO, On the structure of some ancient, but still viable fruits of Indian lotus, with special reference to their prolonged dormancy. Japanese Jour. Bot. **3**:1–20. 1926.

[8] FREER, R. S., Notes on the development of the gametophyte and embryo of *Asplenium angustifolium* Michx. Ohio Jour. Sci. **26**:147–168. 1926.

[9] HOLMAN, R. M., and BRUBAKER, FLORENCE, On the longevity of pollen. Univ. Calif. Publ. Bot. **12**:179–204. 1926.

sperms. Stored in low humidity the percentages of germination fell off suddenly after a few days or weeks, and then for a long period continued at a constant low rate. Stored air-dry most of the pollens survived for one to several weeks. The mean longevity when stored air-dry was about 23 days. The maximum longevity obtained was 336 days for *Typha latifolia*. Of nine families investigated, the Primulaceae ranked first in longevity, followed in order by Leguminosae, Saxifragaceae, and Rosaceae, while the Scrophulariaceae ranked last. The Gramineae, as has been known, stand far below any other family in pollen longevity.—J. M. C.

Cretaceous plants of Western Greenland.—SEWARD[10] has published the results of his investigation of the Cretaceous plant-bearing rocks of Western Greenland, where he spent over two months in the summer of 1921. The plants collected include 15 Filicales, 8 Cycadophytes, 5 Ginkgoales, 19 Coniferales, and 18 Angiosperms. In addition to a general account of the geology of the region, and a full description of the plant material collected, SEWARD presents important conclusions as to the relation of the Cretaceous vegetation of Greenland with floras of other regions, the problem of geological age, and the Cretaceous climate. It is a valuable document for students of the evolution and distribution of plants throughout the northern regions.—J. M. C.

Thelephoraceae.—BURT[11] has completed his extensive monograph of the North American Thelephoraceae. The final paper is mainly the presentation of *Corticium*, which contains 108 species, 47 of which are described as new. A supplement includes species received since the publication of the earlier parts, 20 new species being described under 10 genera. The monograph is very detailed, not only in its description, but also in the complete record of specimens collected. The work as a whole includes descriptions of 113 new species, and the total number of species included in this family will be a revelation to those unfamiliar with the group.—J. M. C.

Micronitrogen determination.—Some improvements of apparatus for the determination of very small amounts of nitrogen are described by FUCHS,[12] by means of which he has reduced the error of determination to 0.007 mg. The apparatus is figured, but the manufacture is protected by law, and it can be obtained only from Alois Schmidt, Schuhbrücke, 42, Breslau. All rubber connections have been eliminated in the shaking apparatus. Complete description of the use of the apparatus is given.—C. A. SHULL.

North American Flora.—The eleventh part of volume VII contains a continuation of additions and corrections to Uredinales.—J. M. C.

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[10] SEWARD, A. C., The Cretaceous plant-bearing rocks of Western Greenland. Phil. Trans. Royal Soc. London **215**:57–175. *pls. 4–12*. 1926.

[11] BURT, E. A., The Thelephoraceae of North America. XV. Ann. Mo. Bot. Gard. **13**:173–354. 1926.

[12] FUCHS, H. J., Zwei verbesserte Apparate zur Mikrostickstoffbestimmung. Biochem. Zschr. **176**:32–37. 1926.

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